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1959-1960

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees	*Annual Dues*
Members	$ 5.00	$ 5.00
Juniors	1.00	2.00
Associates	10.00	25.00
Corporate Members	10.00	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

Lock Joint Concrete Pipe's unexcelled record for durability, efficiency and maintenance-free service is no accident. It is the product of skilled design, meticulous choice of materials and painstaking workmanship.

Lock Joint's well-tested, conservative steel reinforcing design produces pipe of unusual strength and safety. Carefully analyzed select materials, expertly combined by experienced craftsmen, assure unusual durability and permanent high flow characteristics. The watertight, flexible Rubber & Steel Joint permits rapid, economical installation and immediate backfill.

So, when considering materials for water transmission and distribution mains or sewer or culvert lines, make certain to weigh the merits of the pipe that *made its way by the way it's made* — LOCK JOINT CONCRETE PIPE.

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East Orange, New Jersey

Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich.
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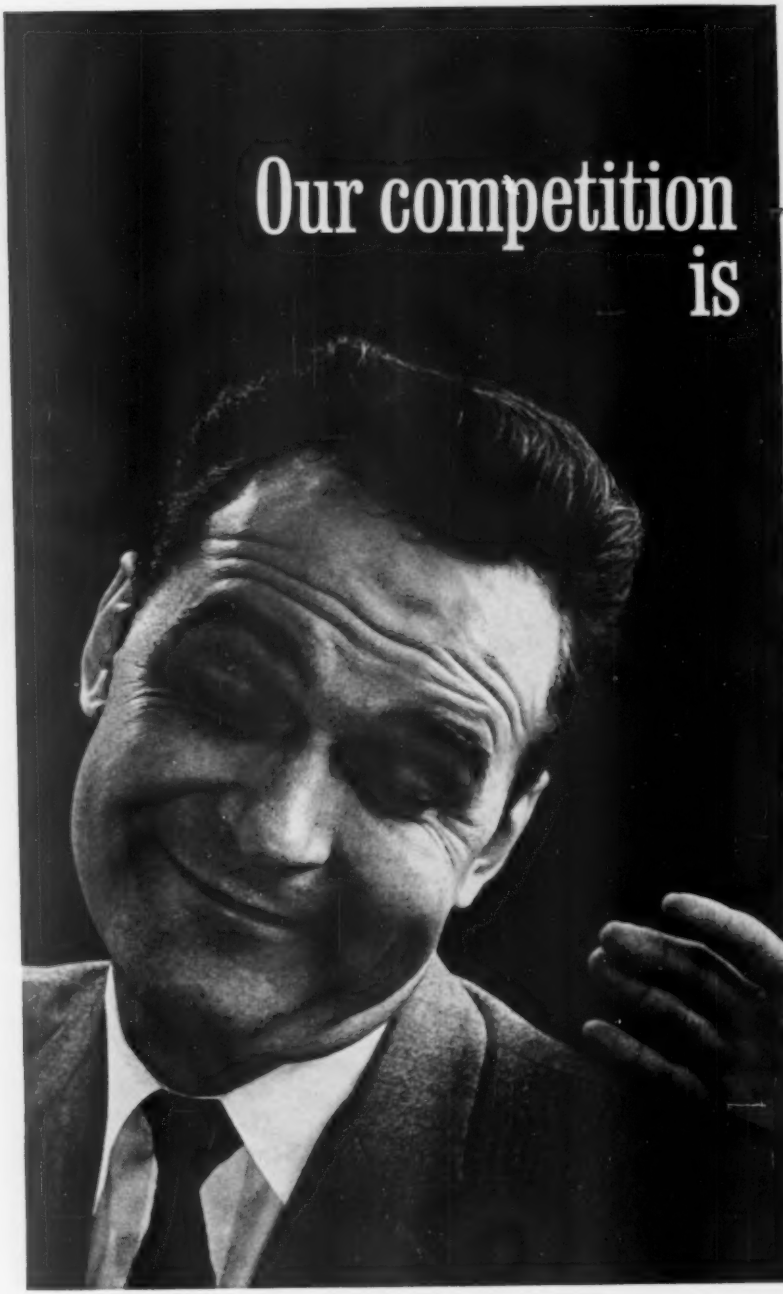
Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous


Our competition
is

The greatest compliment an advertiser can receive is when his competitors imitate his campaign.

That's why we at the Cast Iron Pipe Research Association feel so proud.

For 30 years we have been telling the public about the water problem.

We were the first to come out with consumer national advertising on this problem.

We were the first to inform the people of the need for action at the community level.

We were the first to furnish materials for local advertising programs.

We were the first to offer a comprehensive community relations plan with all necessary materials.

We were the first to issue a guide-to-action booklet which would serve as a step-by-step manual for responsible citizens.

We have been fighting the nation's water problem for over a generation.

And now other pipe companies are coming out with water campaigns, too.

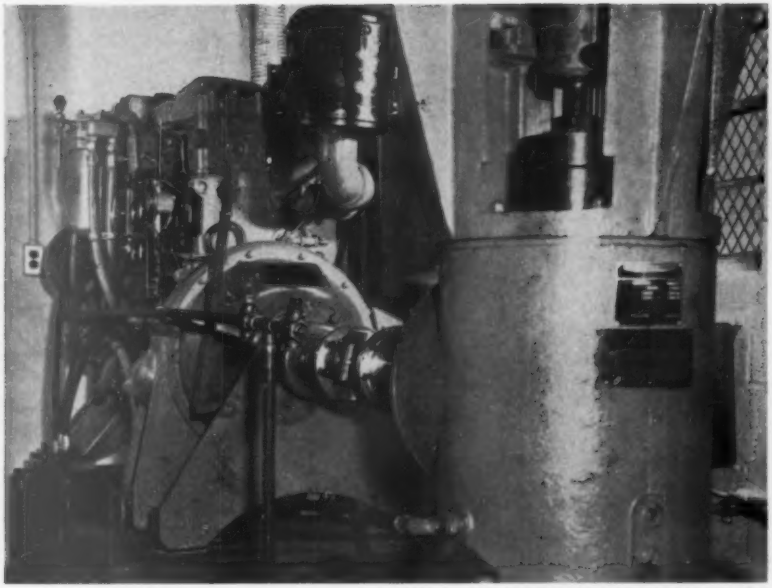
Thank you, competition.

We're flattered.

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE

CAST IRON PIPE RESEARCH ASSOCIATION
Thos. F. Wolfe, Managing Director
3440 Prudential Plaza, Chicago 1, Illinois



DIESEL ENGINE DRIVEN PUMP UNIT
WATER PUMPING STATION
TOWN OF AMHERST, MASSACHUSETTS

This Cummins Diesel engine, rated 122 horsepower for continuous service at 1800 RPM, provides stand-by power for the new water pumping station in Amherst, Massachusetts. Tighe & Bond of Holyoke, Massachusetts, were the engineers for this application, which is capable of discharging 1,000,000 gallons per day at a head of 155 PSI.

Contractors for the installation of the pump and diesel engine were R. H. White Construction Co., Inc., Auburn, Massachusetts.

CUMMINS DIESEL OF NEW ENGLAND, INC.

201 Cambridge Street
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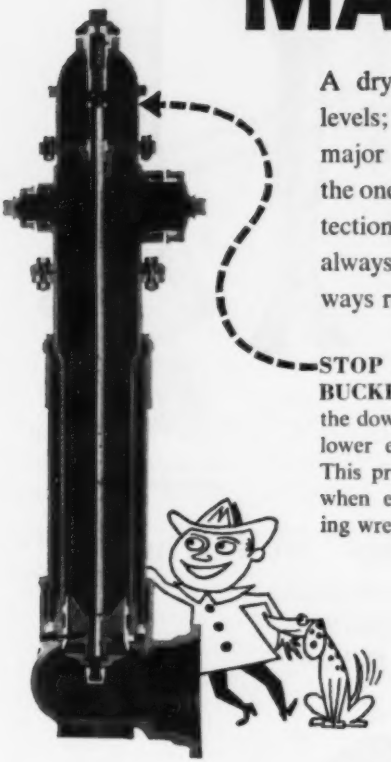
106 Main Street
South Portland, Maine

720 Union Street
West Springfield, Mass.

PUT ALL THESE FEATURES IN ONE HYDRANT AND YOU HAVE A MATHEWS



A dry-head hydrant; adjustable nozzle levels; replaceable barrel—three of many major features that help make Mathews the one hydrant for sound community protection. The Mathews is designed to be always operable, always dependable, always ready to deliver at full pressure.

STOP NUT PREVENTS STEM FROM BUCKLING. The heavy bronze stop nut halts the downward travel of the stem just before the lower end touches the bottom of the elbow. This prevents any buckling stress on the stem when excessive pressure is put on the opening wrench.

AND ALL THESE OTHER FEATURES, TOO: All working parts contained in replaceable barrel • Head can be faced in any direction • Replaceable head • Any nozzle you specify • Nozzle levels raised or lowered without excavating • Leakproof because stuffing box is cast integral with nozzle section • Operating thread only part requiring lubrication • Protection case of "Sand-Spun" cast iron for strength, toughness, elasticity • Available with bell, mechanical joint or flange pipe connections.

Conform to latest AWWA specifications

R. D. WOOD COMPANY

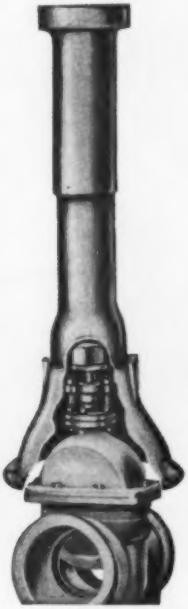
Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers also of Mathews Flange Barrel Hydrants, R. D. Wood Hydrants, R. D. Wood Gate Valves, and "Sand-Spun" Pipe (centrifugally cast in sand molds)

2 Piece Sliding Type
Adjustable Valve Box

2 1/2 or 3 Inch
Heavy Duty
Service Box

2 1/2 Inch
Service Box



3 Piece Screw Type
Adjustable Valve Box

The Three "Bigs" in Buying

1. *Standardization*
2. *Dependability*
3. *Quick Delivery*

ESTABLISHED 1849

BINGHAM & TAYLOR

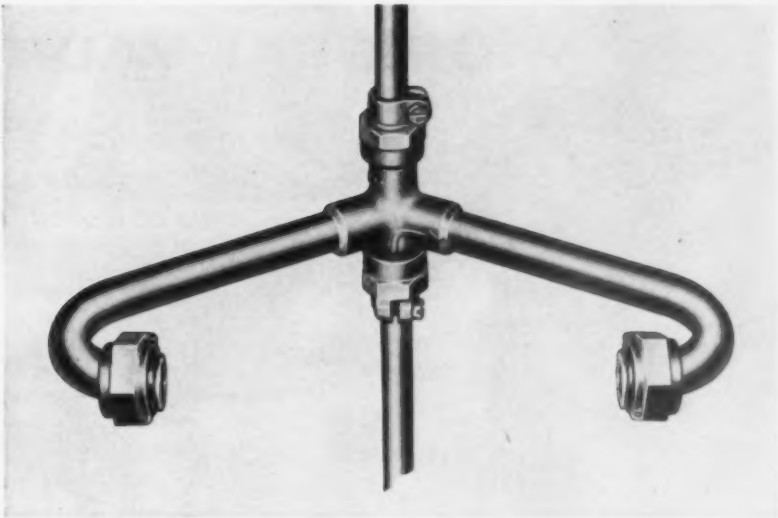
CORPORATION

GENUINE BUFFALO
CAST IRON SERVICE, VALVE, ROADWAY AND METER BOXES

MANHOLE FRAMES AND COVERS

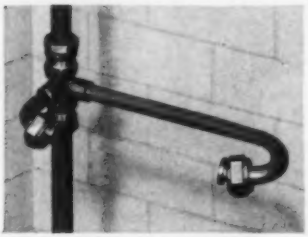
CULPEPER, VA.

NO basement meter mounting can be installed as quickly and easily as Ford's "HANDYHORN"!



The new Ford HANDYHORN (above) eliminates pipe threading, flaring and soldering, puts meter right side up, and provides a permanent physical and electrical connection of the service even when the meter is removed.

Quickest and simplest means of setting meters in basements, the HANDY-HORN can be installed with saw and wrench. It can be used in nearly all vertical piping. Tubes are set at an angle of 120° to permit installation in corners where pipe is at least 2" from wall surfaces.



Where piping is too close to corner . . . the Ford KORNERHORN can be employed. Like the HANDYHORN, this mount does not require flaring or soldering . . . and is quick and easy to install.

Convenient, durable and attractive, the HANDYHORN is the modern way to mount water meters . . . reduce installation costs.

For more information, write . . .

FORD

FOR BETTER WATER SERVICES

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

a boy can open or close the new ORISEAL® VALVE!

An easy turning Curb Valve with all the features you've looked for.

Try it . . . Prove to yourself how easy this valve will open and close. The Teflon coated straight plug turns easy even after prolonged idleness.

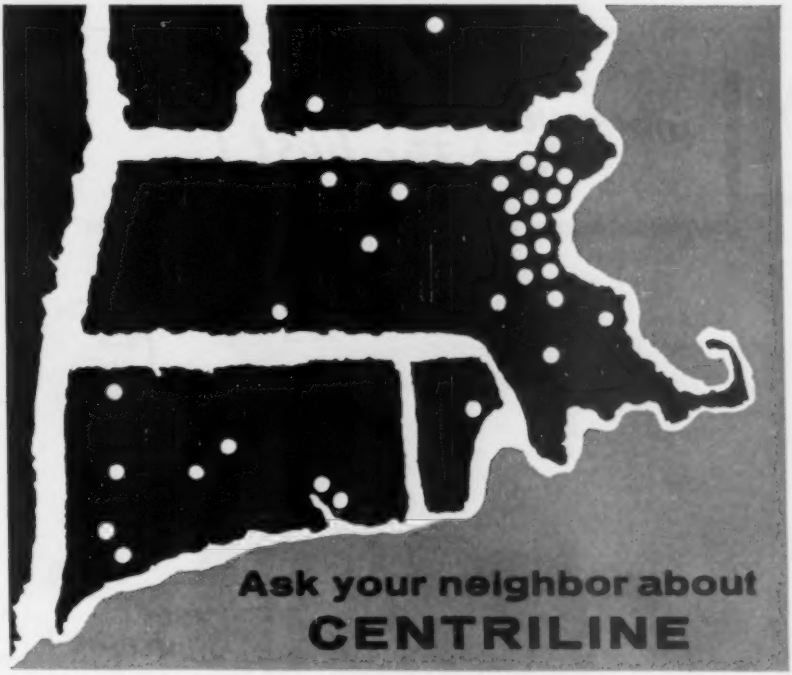
The Key to the dependable long-life performance of the Oriseal is in its simple, practical design. The entire valve assembly is only six parts . . . the three "O" rings in the sturdy valve body, the Teflon coated straight plug . . . the valve cap.

We are happy to offer the Oriseal as another beneficial product developed for the Water Industry . . . the direct result of over a century of experience and tradition for quality "craftsmanship". See your Mueller representative or write Dept. B, Mueller Co., for your copy of "The Oriseal Valve —Test Results".

The Oriseal turns easy without grease . . . has no mechanical seating device to wear or cause sticking . . . the seat is protected against damage and erosion.

MUELLER CO. **DECATUR, ILL.**

Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario.



Spotted on this map are some of the places that have been served by the Centriline Process

Chances are that one of your colleagues has rejuvenated some of his city's piping by Centriline reconditioning. Here's your chance to find out.

Briefly, this process smoothly lines piping—*in place*—with cement-mortar, creating a pipe-within-a-pipe. This vastly increases carrying capacity, stops leakage, prevents corrosion and tuberculation, and prolongs pipe life indefinitely. Pressure goes up, pumping cost goes down, and there's no need to disturb traffic to replace mains. Over 6,000,000 feet of piping, from 4" to 144" diameter, have been treated by Centriline. *Ask your neighbor.*

Write today for a list of nearby officials whose cities have cut inconvenience and costs with this pipe-saving process. Hear what they have to say about Centriline. Then write or call us. We'll be glad to show you how Centriline can help *you* solve the problems of pipe reconditioning in place.

CENTRILINE CORPORATION

A Subsidiary of Raymond International Inc.

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Branch offices in principal cities of the United States, Canada, and Latin America.

when you invest get the best !

PATENTED SILICONE STUFFING BOX PACKING

Split case or frost proof

lower maintenance

greater accuracy

Offices in principal cities

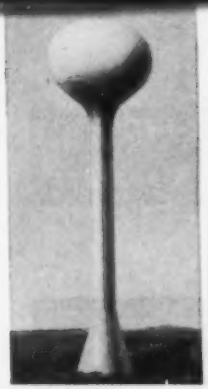
GAMON METER DIVISION

NEWARK NEW JERSEY

WORTHINGTON

When the look of tomorrow is wanted in the moderate capacity range . . .

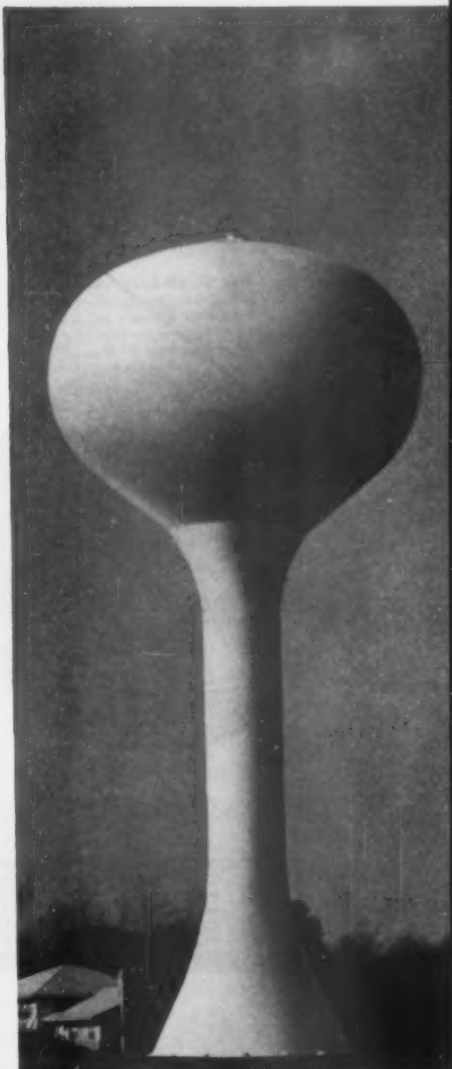
CHOOSE THE PEDESTAL SPHEROID BY PITTSBURGH-DES MOINES



Lansing, Michigan.
250,000 gallons

Humboldt, Iowa.
500,000 gallons

Kingman, Kansas.
500,000 gallons



Annapolis, Maryland.
500,000 gallons

In the evolution of elevated water storage, the PDM Pedestal Spheroid speaks for tomorrow here and now! This smooth and shapely design draws instant attention wherever on view—covers the medium capacity range of 200,000 to 750,000 gallons—and provides the modern-minded community with old-fashioned economy in purchase cost. To find how the PDM Pedestal Spheroid can fit your water service picture, just call in one of our sales engineers. Address our nearest office, without obligation of any kind.

PDM
ELEVATED STEEL TANKS

Pittsburgh-Des Moines Steel Company

Plants at
PITTSBURGH, WARREN, BRISTOL, PA. • BALTIMORE • BIRMINGHAM
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BIRMINGHAM (8) P.O. Box 8641, Ensley Station
DES MOINES (8) 1015 Tuttle Street
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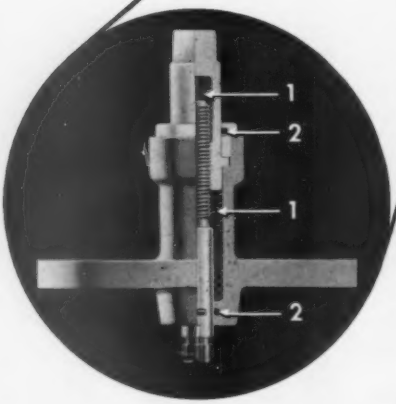
EL MONTE, CALIF. P. O. Box 2021
NEW YORK (17) 200 East 42nd Street
NEWARK (2)..... 744 Broad Street
CHICAGO (3) 679 First National Bank Bldg.
ATLANTA (5) 361 East Paces Ferry Rd., N.E.
JACKSONVILLE... 4066 Ferrarra St.
DALLAS (1) Suite 1703, Southland Center
DENVER (2) 323 Railway Exchange Bldg.
SEATTLE (1)..... 500 Wall Street

WHAT'S INSIDE? A BIG PLUS

AUTOMATIC LUBRICATION AND DOUBLE "O" RING SEALS



Smith Fire Hydrants are easy to operate, inexpensive to maintain and most dependable in meeting severe climate and operating conditions. In addition to maximum flow and simplicity of design, Smith Hydrants now have two additional features of major importance: (1) Automatic lubrication — chamber sealed with "O" Rings contains a permanent type lubricant — temperature range -30° to 200° F. Each time the hydrant is operated, the threads and bearing surfaces are automatically lubricated. (2) "O" Ring Seals — the lower "O" Ring seals the internal pressure, the upper "O" Ring is a combined external dirt and moisture seal. This construction eliminates the conventional stuffing box and packing gland adjustments.

65

FIRE HYDRANTS · VALVES · SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

M-Scope "Master" Electronic Witch
Leak Survey Instrument and Pipe Locator

The transistorized "MASTER" Leak Detector—Pipe Finder Combination is the first dual purpose instrument with separate and independent leak detector and pipe finder circuits. Now you can have two instruments in one without any compromise in performance. The "MASTER" Leak Detector—Pipe Finder incorporates the very latest advances in electronic construction and circuitry in addition to having an exceptionally long battery life. An ideal instrument for any Water Department.

Finding a leak under pavement

Locating a leak at the valve

Location of dead ends

Locating a service

Write for information, demonstration or trial.

PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

PIPE LINE EQUIPMENT

Place your next order with POLLARD

If it's from POLLARD It's the Best in Pipe Line Equipment

NEW HYDE PARK • NEW YORK

Branch Offices: 964 Peoples Gas Building, Chicago, Illinois
333 Candler Building, Atlanta, Georgia

Why this "magnetic" meter attracts more revenue

Since Rockwell first introduced the Sealed Register meter, the center of attraction has been its magnetic drive. But this magnetic principle does a lot more than attract the eye. It attracts more revenue, especially at low flows. That's because there is no friction from a conventional stuffing box, gear train, driving dog or register to cause a drag on the measuring chamber.

This meter attracts substantial savings in maintenance, too, through having fewer parts—only two of which operate in water.

Another big attraction is the hermetically sealed register which cannot fog or become dirt encrusted—hence is always easy to read.

Now you can get these "magnetic" meters in a complete range of sizes from ⅝" through 2". In any size, for any service, these meters will attract more revenue to you. Write for catalog. Rockwell Manufacturing Co., Pittsburgh 8, Pa. In Canada: Rockwell Manufacturing Co. of Canada, Ltd., Guelph, Ont.

POWERFUL MAGNETIC DRIVE

Illustrating how the driver magnet (held in hand) revolves around a watertight compartment at base of register to push the follower magnet, which in turn drives the register shaft.

BE SURE TO REGISTER AND VOTE

SEALED REGISTER METERS

another fine product by

ROCKWELL

Warren Foundry & Pipe Division

of

SHAHMOON INDUSTRIES, INC.

Manufacturers of

CAST IRON PIPE & FITTINGS

Made in Accordance with Latest Specifications

Including TYTON Joints

Either Cement Lined or Tar Coated

Pipe Made in Everett — Centrifugally Cast in Sand Lined Molds in 16′ L/L

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"First we thought we'd have to move
Oncle Bull but Tyton lays so easy
he ain't even stirred."

U.S. cast iron **PIPE** FOR WATER SEWERAGE AND

no fuss, no muss, no cuss!

Fact! Not a worry in a workload with Tyton Joint® pipe. This easy-going pipe is so easy to assemble . . . lays so fast your ditcher has to step on it to keep ahead.

Tyton® is so simple. Only one accessory needed. No bell holes. No caulking equipment. No nuts or bolts to fasten. Minimizes weather worries too. You can lay Tyton in rain or wet trench. That means more working days, more production, lower installation cost.

Get the facts on time, money, trouble-saving Tyton Joint pipe. You'll sell yourself. Call or write today.

U.S. PIPE AND FOUNDRY COMPANY
General Office: Birmingham 2, Alabama

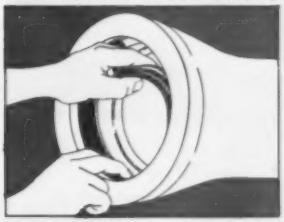
A Wholly Integrated Producer from Mines and Blast Furnaces to Finished Pipe.

INDUSTRIAL SERVICE

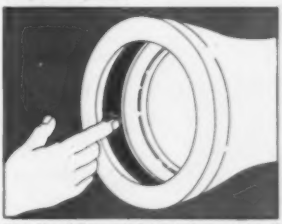
CAST IRON

TYTON®

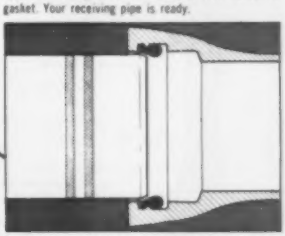
ONLY FOUR SIMPLE ACTIONS



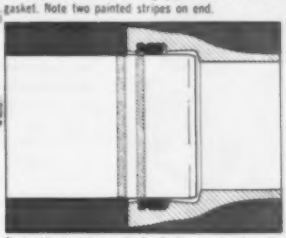
Insert gasket with groove over bead in gasket seat . . . a simple hand operation.



Wipe film of Tyton Joint® lubricant over inside of gasket. Your receiving pipe is ready.



Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.

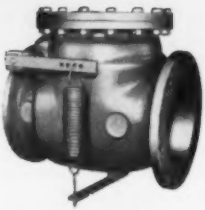


Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . . fast, efficiently, economically. Could anything be simpler?

EDDY New Improved Products Meet Modern Needs

EDDY Fire Hydrant

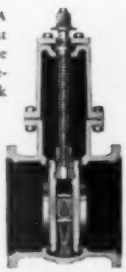
- Improved, streamlined, modernized
- Optional break-flange
- Large diameter barrel
- New self-sealing main valve packing
- Requires no lubrication
- Opens *with* pressure
- Closes *against* pressure
- Underwriters' listed
- Standardized, interchangeable parts



EDDY Check Valves

Completely new designs of horizontal swing check valves are available in sizes from 4 through 12 inches. They operate dependably in either vertical or horizontal positions and incorporate construction features which provide unusual flexibility of operation. These valves may be converted in the field from plain to single- or double-lever operation to meet changing requirements. Other check valves up to 24 inches.

EDDY Gate Valves



In addition to the regular line of EDDY Taper Seat AWWA gate valves, EDDY now offers a newly designed parallel seat AWWA gate valve in sizes through 12 inches. This valve has been specifically engineered to provide long, trouble-free service. Working parts are designed with heavy, thick section and large seating surfaces for dependable operation and improved wearing qualities. The valve has two-point, free-floating wedging for minimum friction and maximum operating ease. Other AWWA gate valves are available through 48 inches.

H. R. Prescott & Sons, Inc.
NEW ENGLAND SALES AGENTS
Box 7 — Greendale Sta.
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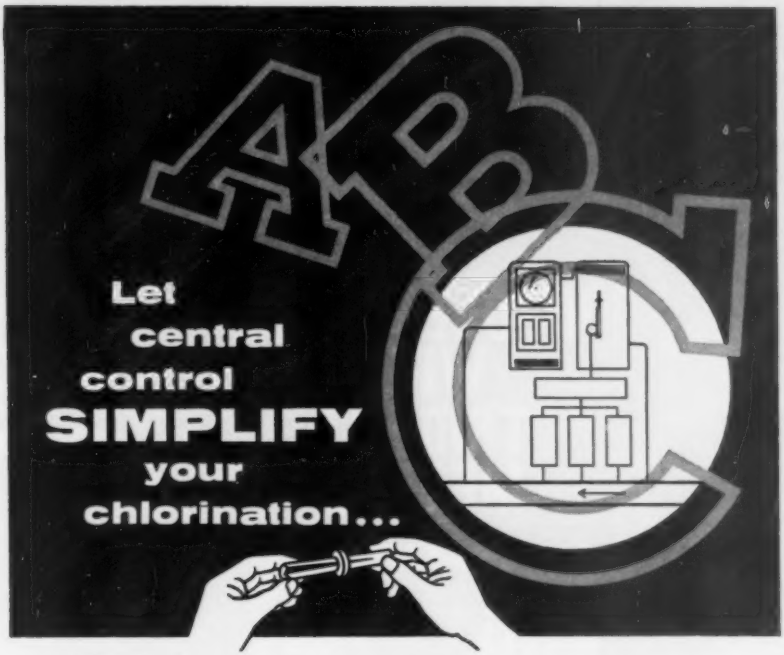

W&T **COMPOUND-LOOP CONTROL**

By residual analysis and information feedback, Wallace & Tiernan Compound-loop Control adjusts chlorinator feed rates to changing water flows and chlorine demands. You can add W&T Remote Residual Recording and Controlling Components throughout your water system and centralize control at any desired location. You select the desired residual on a central panel and the Compound-loop System maintains that residual faithfully.

Remote recording by W&T gives you duplicate residual records and minute-to-minute information where it helps guide operation. Remote controlling by W&T lets you adjust a chlorinator miles away. And W&T Remote Components adapt to almost any system, any type of control.

With remote residual recording and controlling by Wallace & Tiernan you centralize control... save time and operating expense... extend the advantages of the Compound-loop method.

For more information, write Dept. S-142.63

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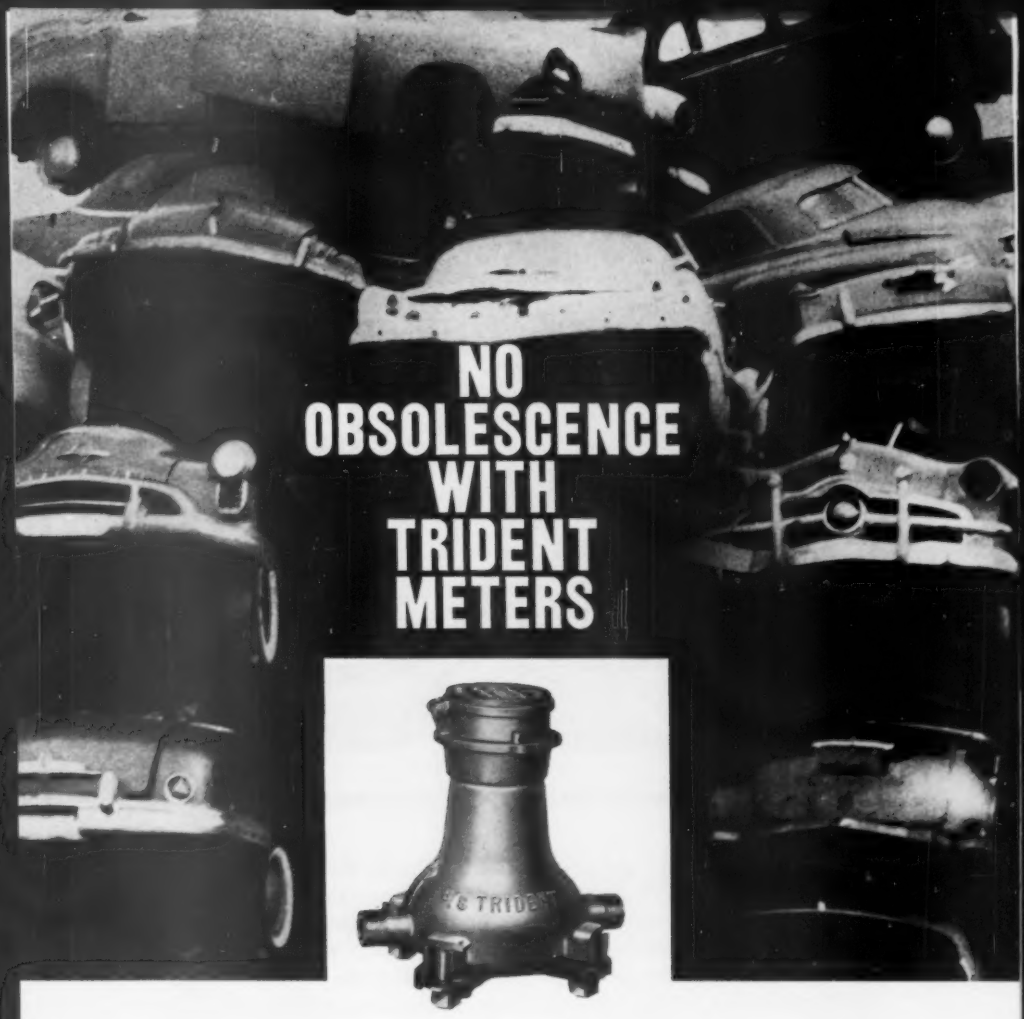

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CHEMICAL METHODS OF WEED CONTROL IN RESERVOIRS

BY VINCENT MASCIA*

[Read at Chemists' Session, Nov. 19, 1959.]

Much has been said about forestration, weed control and sanitary problems on watersheds, but little can be found on weed control in potable water supplies except by mechanical means. This paper will try to impart to you some knowledge on chemical weed control in potable water supplies obtained several years ago in connection with two water supplies in Westchester County, New York. Small shallow reservoirs or large reservoirs with shallow areas where aquatic vegetation such as milfoil, wild celery, pondweed, cattails and pond lilies are in abundance usually impart various tastes and odors in the water such as musty, grassy, fishy, moldy and earthy depending on whether the vegetation is in bloom or decaying. Algae blooms usually prevail where weeds are present in abnormal quantities.

In the past few years a great deal of research has been in progress in relation to tastes and odors caused by actinomycetes. Investigations have shown that actinomycetes cause many tastes and odors in water that are similar to those imparted by algae and weeds. It is therefore apparent that tastes and odors in water supplies are not caused entirely by one group of organisms, but may be due to a combination of forms. The actinomycetes in water supplies usually start from spores that grow into very small filaments which cling to some source of nutrition such as algae, organic matter and *weeds* in the shallow areas of the reservoir. It is during the early growth of the filaments that actinomycetes produce high concentrations of tastes and odors. It follows then, that if the sources of nutrition can be eliminated then it would be difficult for actinomycetes to grow in large

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numbers. Algae can be effectively controlled with copper sulphate, but weeds are somewhat more troublesome.

There are three types of rooted aquatic vegetation, namely the emergent plants like cattails, the floating leaf plants such as water lilies, and the submerged type such as eelgrass and milfoil. Small amounts of rooted vegetation are usually beneficial to water supplies, because they liberate oxygen into the water, but in large quantities they cause tastes, odors, high color and turbidity, hinder the fish population, and may support mosquito breeding. The growth of water weeds is influenced by light penetration, availability of nutrients, and temperature. Most plants reproduce by means of seeds, others by root-runners, tubers, winter buds and plant stems. These facts explain some of the difficulties that arise from mechanical control of water weeds, such as hand raking, dragging chains, pulling cables, underwater saws and many other innovations. The disadvantage of these methods are the oxygen depletion from the cut decaying weeds, and the rooting of the cut fragments.

Weeds in general are not controlled by the copper sulphate treatment. During recent years a large variety of chemicals have been used for the control of submerged aquatic plants, mostly in non-potable lakes and streams. Some of the chemicals are soluble in water, toxic to fish and human beings, especially the arsenic compounds. It is for these reasons that the chemicals are not recommended for public water supplies. Most chemicals are effective for one season only as the roots and seeds of the plants are not affected. Therefore the ideal chemical for weed control in potable water supplies should be non-toxic, insoluble in water, heavier than water, easy to apply, effective for a long period of time, and economical to use. Except for toxicity to fish a chemical almost meeting these specifications was developed by the Cloroben Corporation of New Jersey some twenty years ago and was called Benoclor 3. This chemical is a chlorinated hydro-carbon, in this case benzene. It has a pungent odor, is insoluble in water, has a specific gravity of 1.45, and when applied under water diffuses very slowly on the plant foliage and lake bottom. It is applied under water by mechanical dispersion, using atomizing nozzles under pressure from a tank in a boat. The probable killing is through roots, cells, walls, and the cir-

culatory system of the plant. Any chemical remaining on the bottom continues to act on the organic life and remains in the silt for several years after initial introduction. As previously mentioned Benoclor is toxic to fish so that if small areas are treated every few days allowing clear water areas at all times the fish may be spared. The rate at which the Benoclor is applied depends on the density of the weeds, the time of application and the type of weeds involved. The dose ranges from 10 to 25 gallons per acre. Weed-control work is best done in the spring of the year before blooming time so as to prevent re-seeding. Where this interferes with fish life, then an early fall application is recommended.

Submerged weeds may be treated without cutting, but the emergent weeds such as cattails, picheral weeds, tules and sedges should first be cut below the water surface or as near the bottom as possible and the cuttings removed before treating with Benoclor. Semi-emergent weeds, such as alligator grass, should be treated with a modification of Benoclor before they grow above the water surface. If the plants have attained tops, they may be treated by aerial spraying. This treatment requires a very high dosage of one gallon per square rod. Free-floating weeds, such as water hyacinth, lilies, etc., are also controlled by aerial spraying with the modified Benoclor.

In the early summer of 1945 after several years of weed nuisances mostly with milfoils in some areas of the Larchmont, New York, reservoir it was decided to treat approximately two acres with Benoclor on a trial basis. This reservoir has a capacity of 150 m.g., an average depth of 15 feet and a watershed area of 3 square miles. All the water serving the village must first pass through a one-m.g.d. filter plant located 1000 feet below the dam site where the water is aerated, coagulated with alum, chlorinated (break-point), settled, carbon added and then filtered.

The area selected for the Benoclor treatment was approximately 1000 feet from the intakes at the dam and 500 feet from the mouth of the stream discharging into the reservoir. The dosage used was 15 gal. per acre and was applied in about five hours with equipment loaned by the Cloroben Corporation with complete instructions. Approximately eight hours after the application of the Benoclor a brisk wind developed causing the

reservoir water to become very choppy and soon thereafter a pronounced medicinal odor was observed in the aerator. The carbon dose was increased at once from the normal of 2 p.p.m. to 4 p.p.m., and this was the only change made in the operation of the plant. The effluent from the plant was free from any medicinal odor at all times. The odor persisted in the aerator for approximately three weeks after which the carbon dose was set again at 2 p.p.m. The aerator alone seemed to have reduced the odor by about 90% because samples taken from the settling basins before the carbon was introduced showed a very slight medicinal odor. During the three weeks not one consumer complaint was received by the Department due to taste or odor. Our first consumer was only three hundred feet from the filter plant.

On the fifth day the weeds in the treated areas seemed to have lost their color and shortly thereafter disintegration of the plants began. The following year approximately 90% of the treated areas were free of weeds.

In the fall of 1947 one acre of the Mamaroneck, New York, reservoir was treated with a dose of 25 gallons. The area treated contained milfoil, wild celery, cattails and water lilies. Here again a medicinal odor was noticed in the aerator shortly after treatment and was completely eliminated with the addition of 5 p.p.m. of carbon for a period of only 15 days as compared to 21 days with the Larchmont plant. This was due to the greater dilution occurring in the Mamaroneck reservoir which had a watershed area of 11 square miles. The treatment in this case was 70% effective.

Results obtained from the two applications show that odors after treatment with Benoclor can be completely eliminated by the use of activated carbon. Aeration and dilution also greatly reduce the after-effects. No taste or odor complaints were received in either case after treatment.

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AUTOMATIC CONTROL OF CHEMICAL ADDITION

BY R. H. BABCOCK*

[*Read at Chemists' Session, Dec. 17, 1959.*]

Automatic control is necessary in the water treatment field when chemicals such as alum, chlorine, etc., are to be added in proportion to flow. Control is also required for the correction of concentrations such as pH, fluoride, and chlorine. Both of these requirements are very important in today's water treatment plants which, in many instances, are operated at varying flow rates. While it is possible to manually control the feeders which operate on this type of schedule, it is not in the real sense of the word practical. Many of these functions cannot be carried out with the manpower normally available in a water treatment plant. The result is that automatic control of chemical addition must be applied in varying degrees to almost all modern water treatment plants.

Two basic types of control are used: the so-called open loop and the closed loop. Open loop is typified by the usual method of setting a chemical feeder in proportion to flow rate, the feeder being operated by a signal from a water flow meter with no actual measurement of the amount of chemical being fed. The accuracy of this system depends entirely upon the accuracy of the feeder and its controls. The second type, closed loop, is typified by a liquid alum flow system where transmitting measurement equipment is used. In this system, an actual measurement is made of the quantity of alum being fed. This is compared against a desired quantity of alum and corrections continuously made to hold the actual quantity equal to the desired quantity. This control technique provides a high degree of accuracy.

By and large, most of the automatic control problems concern addition of chemicals in proportion to flow—the normal way in which coagulants, activated carbon, chlorine and fluorine are added. In the case of lime or soda ash, such proportioning is practical where there is a constant pH of the influent.

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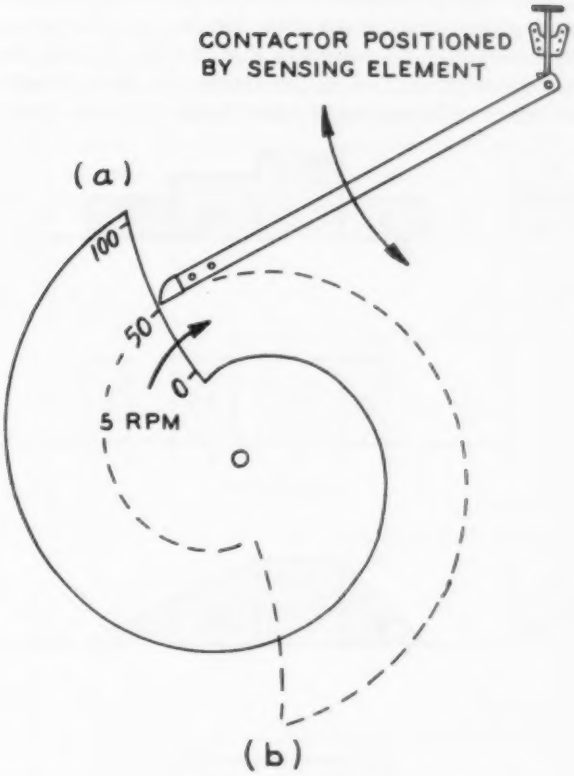
Open Loop Control

The most common method of addition in proportion to flow is open loop control, with the impulse duration type most widely used. Impulse duration control is applicable to dry feeders of both the volumetric and gravimetric type, to chlorinators of all types, and to positive displacement metering pumps. Although, for practical purposes, it is universally applicable, it is not always the wisest choice when all factors are considered. Impulse duration control is based on a cam contacting mechanism, which operates in the manner illustrated by Figure 1. The contactor is positioned by a sensing element and is operated in conjunction with a cam turning at a constant rate. Cam cycles for chemical feeder control range from 12 seconds to 60 seconds per cycle. One type of contactor rides under the cam at the beginning of the cycle and there is no signal. When it leaves the trailing edge of the cam, the signal starts and continues until the leading edge of the cam is again encountered, at which time the cycle repeats itself. The result is that at 50 per cent of scale on a 12-second cycle, electrical contact is made during the last six seconds of the cycle. This type of control does not depend upon signal level but only signal duration. It is basically the way integrators or flow totalizers operate.

Most impulse duration controllers are conventional integrating flow meters with an additional relay to carry the electrical load of the starting equipment for the feeder. Figure 2 illustrates the type of signal in impulse duration control. The upper half of the figure illustrates a hypothetical case in which flow actually makes stepwise changes, each of which is one cycle in duration. The total flow, or the area under the flow curve, is equal to the area under the impulse duration curve; therefore, 100 per cent accuracy is being achieved. In the lower part of the figure, the flow curve is changing linearly over both a 1- and 2-cycle period. There is no difference between the integrated area under the flow curve and under the pulse curve. In the long run, very small errors will be occurring between the impulse duration signal and the actual flow measurement. The instantaneous pulse will be in error from the flow but will normally average out over a period of time.



Measurement at 50%

(a) Beginning of cycle - contactor drops under cam - no signal.
(b) 6 seconds later - contactor leaves cam - signal starts

FIG. 1

The advantage of impulse duration control is that a relatively inexpensive flow meter is adequate for the job. In many cases it has been suggested to engineers that if there is any possibility of needing feeder control in the future, the flow meters should be purchased with impulse duration units built into them. Since

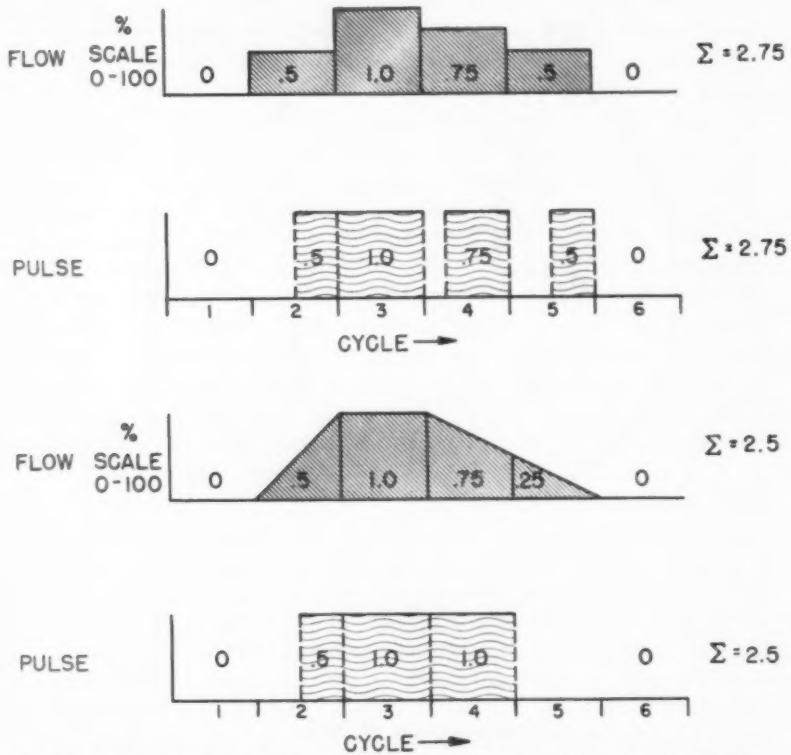


FIG. 2—RELATIONSHIP OF FLOW TO TOTALIZED (INTEGRATED) IMPULSE DURATION SIGNAL (OPEN LOOP CONTROL)

it is merely a matter of adding a relay during manufacture of the conventional integrating flow meter, the expense is small. Once this equipment is in the meter, it is possible to control feeders in the future without instrument modification. The feeder adaptations for this type of control are inexpensive. Only a 3-

phase motor and an across-the-line magnetic motor starter are needed. Three-phase motors and across-the-line motor starters are used for long life and low maintenance of the feeder motor. The comments with regard to inexpensive adaptation of the feeder do not apply to chlorinators, which require a device for conversion of the impulse duration signal to a vacuum signal that may run into hundreds of dollars. Other possible means of control for chlorinators will be discussed later in this paper.

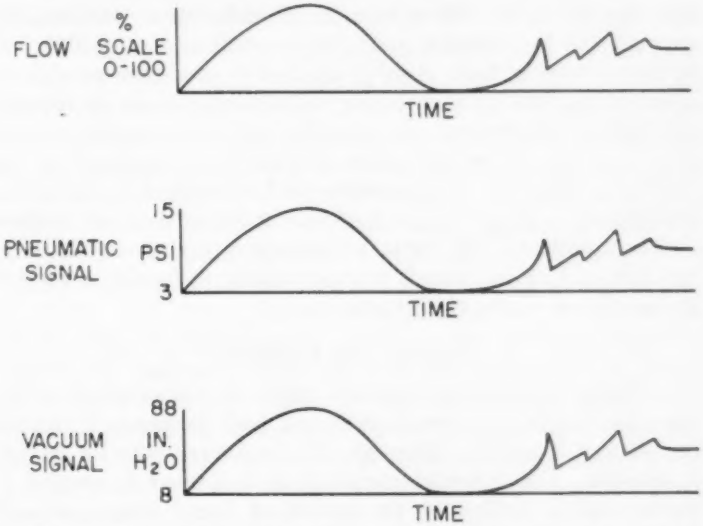


FIG. 3—RELATIONSHIP OF FLOW TO PNEUMATIC AND VACUUM SIGNALS (OPEN LOOP CONTROL)

Another type of open loop control for chemical feed utilizes pneumatic transmission. It is readily adaptable to all of the previously noted types of feeders. Figure 3 illustrates the relationship of flow to the pneumatic signal. It is observed that one follows the other exactly, with none of the inaccuracy present in the impulse duration system. This system requires relatively inexpensive instruments. Its total cost runs about the same as an impulse duration controller but usually it requires a rather expensive feeder adaptation in the form of an air motor which

varies the feed rate in proportion to flow. In addition, it requires a 20-pound air supply. This type of control is readily applied to all types of feeders but most logically applied to the gravimetric type. It can be applied where there are rapidly changing flows.

A related type of control is based on vacuum transmission which utilizes a vacuum transmitter consisting of a mechanical flapper-nozzle relationship device similar to that used in the pneumatic systems except that air is drawn through it rather than applied to it. The ejector in the chlorinator furnishes the vacuum and the vacuum controller constitutes a controlled leak in the vacuum system. Readily applied to most modern chlorinators, it requires an inexpensive instrument and an inexpensive chlorinator adaptation. It provides accurate control of the chlorinator in proportion to flow with neither compressed air nor electricity required. It is probably the best method of controlling chlorinators in proportion to flow rate in the smaller and medium size installations. The main advantage is that it continues to function as long as there is a water supply to furnish a vacuum to the ejector of the chlorinator.

Closed Loop Control

Closed loop control actually makes a measurement of the quantity of chemical being delivered and compares it against the desired quantity. Through this technique, precise control is possible. For practical purposes, it is limited to control of liquids and is typified by the control of liquid alum flow with an integral orifice differential pressure cell. Here, the liquid alum flow to the injector is regulated by a control valve which, in turn, is actuated by a recorder-controller receiving a measurement signal from an integral orifice differential pressure cell transmitter. Better control than is possible with volumetric feeders and positive displacement pump is readily achieved. Normally no repumping of the chemical is required and the over-all installation is simplified. Control of alum feed rate in proportion to plant influent is readily accomplished with this type of equipment, as illustrated by Figure 4. In this case, the control index of the alum flow controller is set by the plant influent rate. If the influent rate changes, the alum rate changes in proportion. Dosage

is adjustable within the instrument by changing the ratio between the two flows. This type of control is applicable to alum, caustics, acids and, in general, all fluids normally utilized in water treatment practice.

It should not be overlooked that chemicals fed as liquids in many cases result in greater efficiencies than realized with the dry form of the same chemical. An example is alum. At the Salem and Beverly (Mass.) Water Supply Board filtration plant, an average reduction of 19 per cent in alum consumption (dry weight) has been realized by conversion from dry to liquid alum.

A comparison of the expected accuracies with various types of control reveals some interesting facts (See Table 1.) For dry feeders and metering pumps, simple, inexpensive, impulse duration control is more precise than other types, providing the rates of flow change slowly. For chlorinators, the simple inexpensive vacuum transmitter is sufficiently accurate to handle most applications. Liquid feed control is most accurately accomplished by feed-back ratio control. Except with rapidly changing flows, pneumatic control of dry feeders and metering pumps is least accurate. For normal water works installations, it can be concluded that impulse duration control is the logical selection for dry feeders, and metering pumps with vacuum control for chlorinators. Feed-back ratio control is most accurate for solution feed with the additional advantages of recording and continuous monitoring of feeder operations. It is apparent that accurate feeder pacing does not necessarily require elaborate and expensive equipment.

Concentration Control

A second type of closed-loop control is concentration control in which the actual concentration of a substance is measured and the dosage then corrected so as to maintain concentration at a constant level. This type is illustrated by pH control, residual chlorine control, fluoride control, etc. Except for pH control, it has not been widely adopted in water treatment practice to date but should be in the future.

Figure 5 shows a typical closed-loop control pH system. The pH electrode is located in the pipeline and transmits an electrical signal to a pH recorder-controller which, in turn, fur-

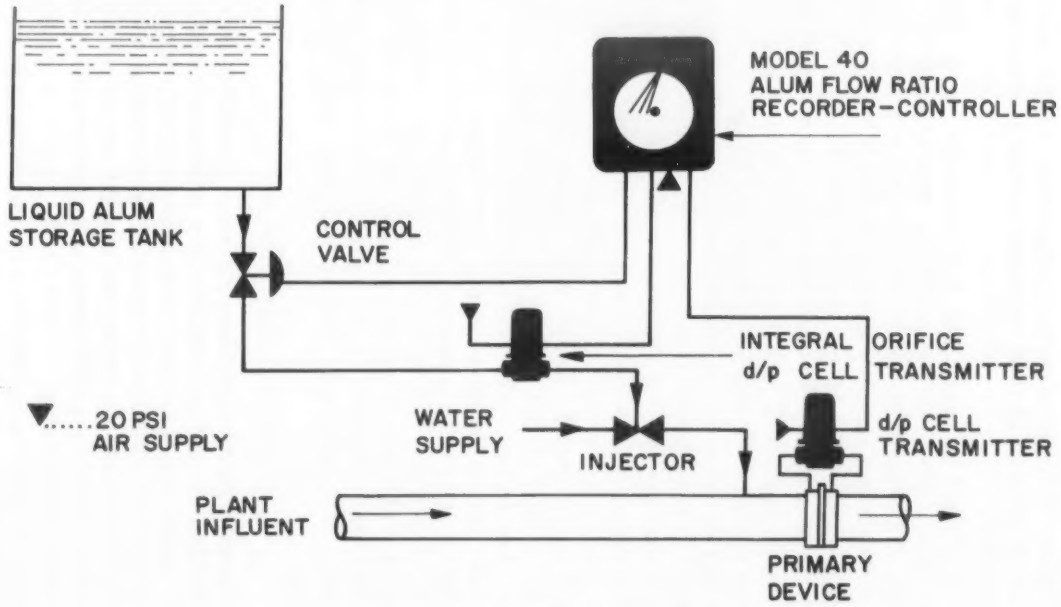


FIG. 4—SCHEMATIC DIAGRAM OF CLOSED LOOP CONTROL OF LIQUID FEED

TABLE 1—ERRORS FOR DRY, LIQUID AND GASEOUS FEEDER PACING AT 100% OF FLOW

	Impulse Duration (% pulse)		Pneumatic (3-15 psi)		Vacuum (8-88 in. H_2O vacuum)	
	Maximum	Probable	Maximum	Probable	Maximum	Probable
Dry Feeder Volumetric	5.75%	5.05%	6.50%	5.12%		
Dry Feeder Gravimetric	1.75%	1.25%	2.50%	1.50%		
Metering Pump	2.75%	2.13%	3.50%	2.29%		
Chlorinator	5.75%*	4.18%*	5.50%	4.15%	7.00%**	6.07%**
Feedback Ratio Control (Liquids)			2.00%	1.41%		

Individual Accuracies

Impulse Duration	.75%	Dry Feeder (Vol.)	5%	Pneumatic Operators	1%
Pneumatic	.5%	Dry Feeder (Grav.)	1%	*Impulse Duration Vacuum	
Vacuum	1.0%	Metering Pump	2%	Converters	1%
		Chlorinator	4%		
		**Chlorinator (Vacuum Control)	6%		
		Feedback Loops	1%		

Maximum Error

$$= E_1 + E_2 + E_3 + \ldots\ldots\ldots\ldots E_n$$

Probable Error

$$= \sqrt{E_1^2 + E_2^2 + E_3^2 + \ldots\ldots\ldots\ldots E_n^2}$$

nishes a pneumatic signal to operate a pneumatic control valve and admit chemical for pH correction.

Some important cautions must be observed in the application of pH control. Although pH appears to be linear on the scale, it is actually a logarithmic value and the scale is a linear expression of a very non-linear characteristic. A pH change of 1 unit represents a tenfold change in H+ concentration.

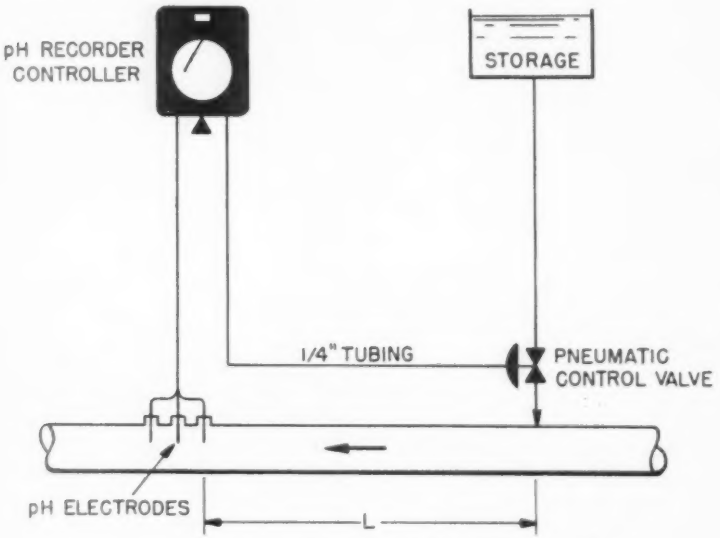


FIG. 5—SCHEMATIC DIAGRAM OF pH CONTROL SYSTEM
(CLOSED LOOP CONTROL)

Note that Figure 5 shows a dimension "L". Figure 6 establishes "L" as the minimum distance between the point of addition and the point of measurement. This minimum distance is best established by laboratory experiment in which units of acid or alkali to be used in the actual plant are added to the water and the pH observed over a period of time. For different dosages, a family of curves similar to Figure 6 might result. The value for "T" should be the longest time required to reach stability. Therefore, "L" becomes the velocity $\times$ time. If acids or alkalis are to be delivered to the water in liquid form, time is not nor-

mally a problem because the reaction rate is, for practical purposes, instantaneous. However, with materials such as dolimitic limestone, reaction times are very long. To control a system where the dimension "L" is less than the minimum distance is difficult, if not impossible. There will be wide differences between

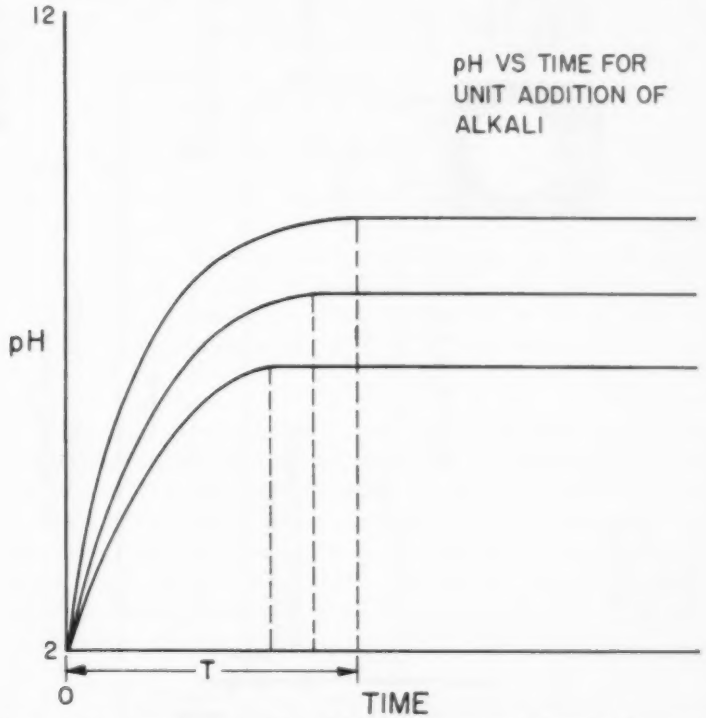


FIG. 6—L = VELOCITY × T = MINIMUM DISTANCE BETWEEN POINT OF ADDITION AND POINT OF MEASUREMENT

the laboratory pH measurements of the water (taken at a point farther downstream) and those shown on the recorder-controller. Also the recorder-controller will have a difficult time controlling because the reaction is in a transient state. Many pH installations in water treatment plants do not operate satisfactorily simply because this simple laboratory procedure was not per-

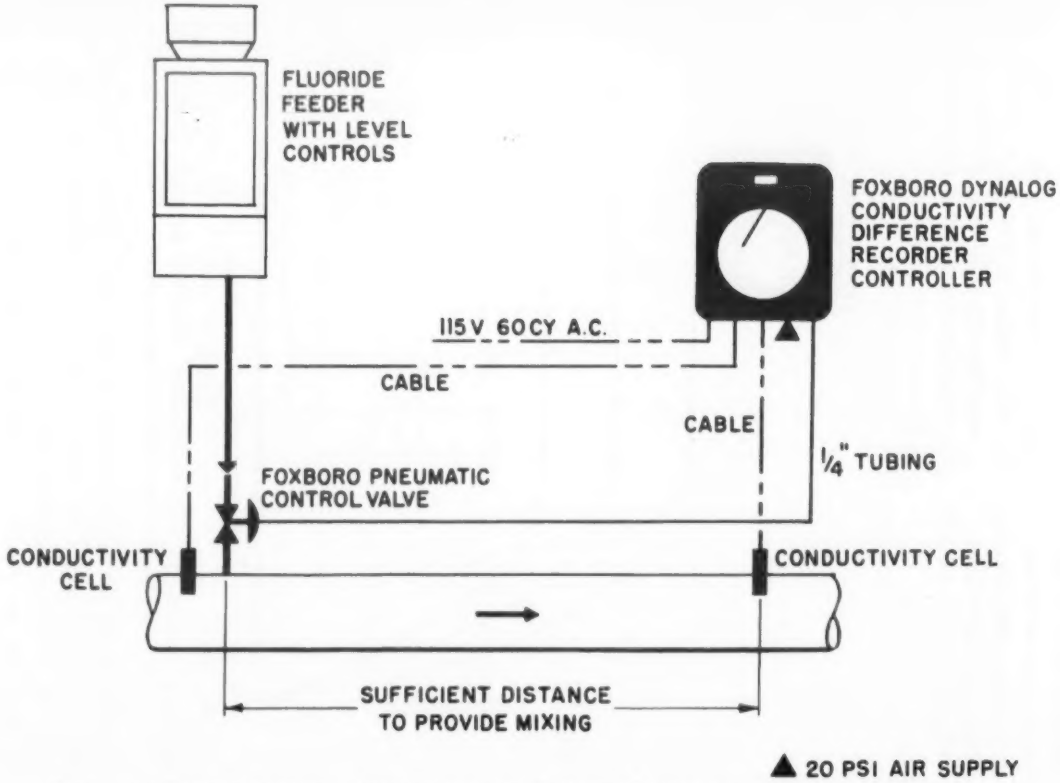


FIG. 7—SCHEMATIC DIAGRAM—INSTALLATION OF FLUORIDE CONCENTRATION RECORDER-CONTROLLER

formed before the installation was designed and placed in service. Another effect which must be considered in the application of pH recorder-controllers is the buffering capacity of the water. The pH control point should be selected with accurate knowledge of the buffer points.

Although not always practical from a chemical handling standpoint, pH correction through the feeding of a liquid is preferred to dry chemical feed with the controller changing the rate of a dry feeder. Serious lags in the dry feeder many times make pH control with this type of feed almost impossible.

One means of avoiding or minimizing feeder delays on concentration control is to use a volumetric type of dry feeder, operating at a fixed rate higher than the maximum required and controlling feed with a control valve (Fig. 7.) Level controls are necessary on the feeder to prevent flooding the solution tank. This results in an essentially liquid feed system providing the dry chemical is readily soluble. The feeder is being used for continuous preparation of a solution. The lag involved in changing feed rate and in turn changing the concentrations in the solution is eliminated.

The material contained in this paper has been an attempt to summarize some of the basic methods and techniques of control of chemical addition to water treatment processes. Such factors as plant flow characteristics, accuracy of dosage required, and capabilities of plant personnel should all be considered before a system is selected. Proper selection of a system can help the plant realize better treatment at a minimum expenditure for chemicals.

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EXPERIENCES IN THE APPLICATION OF FLUORIDES TO PUBLIC WATER SUPPLIES IN NORTHEASTERN MASSACHUSETTS

BY HERBERT D. NICKERSON*

[*Read December 17, 1959.*]

The addition of fluorides to water, known as fluoridation, is widely practiced. In the United States, nearly 35 million persons in some 1,772 communities are being served fluoridated water. Of the 351 communities in Masschusetts, approximately 60 have taken some official action on the issue of fluoridating the municipal water supply. The outcome in some of these towns and cities is indeterminate, uncertain or pending. Of the remaining communities, 23 with a population of 250,000 are receiving fluorides in their public water supply.

Justification for the addition of fluorides to water has invoked wide discussion and has resulted in approval by many scientific organizations. Some communities are adding fluorides to maintain an optimum level of 1.0 ppm of equivalent fluorine in the public water supply, as it has been satisfactorily demonstrated that at such a concentration no tastes or odors will be created, and this concentration is effective in the prevention of dental caries in children.

The Massachusetts Department of Public Health issued a statement of policy relative to fluoridation of public water supplies, which was approved by the Public Health Council at its meeting on October 9, 1951. This statement is as follows:

"After careful evaluation of the results of research and experience in this and other states, health authorities have concluded that the application of fluorides to public water supplies is the best method available at this time for the reduction of dental caries. Accordingly, the Massachusetts Department of Public Health recommends the fluoridation of public water supplies where there is a deficiency in the natural fluoride content of the water.

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"The Department will consider for approval an application from the local Water Department or Company with the endorsement of the local Board of Health or Health Department for the fluoridation of the public water supply under the following conditions:

"1. The type of equipment, the point of application, the fluoride compounds and the dosages to be used must be approved by the Department.

"2. The sampling program established by the Department must be followed by the water department officials.

"3. Adequate testing facilities must be provided and a record of the operation of the equipment should be submitted to the Department at the end of each month on an approved form."

The Department will provide technical assistance in establishing recommended controls and procedures to the local board of water commissioners or water company through the Division of Sanitary Engineering. The Division of Dental Health will assist the local board of health or health department in making adequate pre-fluoridation and post-fluoridation dental evaluation, when such surveys are considered desirable.

The support of the fluoridation of water supplies has been recently reaffirmed by Commissioner Alfred L. Frechette of the Massachusetts Department of Public Health in a statement, describing this procedure as "the safest, simplest, and most effective method of reducing tooth decay." He commented further that Massachusetts has always been a public health leader in disease prevention and control, but when it comes to fluoridation, our state is lagging behind the rest of the country. Washington, D.C., with over a million population has been fluoridating since 1952. Other large cities now doing so are Cleveland, Providence, San Francisco, Chicago, Baltimore, St. Louis, Milwaukee, and Denver.

In the section of Massachusetts which the Department of Public Health refers to as the Northeastern Health District, there are 65 communities. Of these 65 communities, 12 are presently adding fluorides to their water supply. These communities are: Danvers, Essex, Andover, Topsfield, Salem, Hamilton, Wilmington, Kalmia Woods Development in Concord, Winchester, Lynnfield Center Water District, Middleton, and Beverly. Two

communities have recently voted out fluoridation—namely, North Andover and Reading. Wenham approved the addition of fluorides prior to 1958 and is presently awaiting the ruling of their town counsel on its legality with respect to Chapter 254 of the Acts of 1958. Cambridge has just voted to add fluorides to the water supply. Other communities in the Northeastern Health District have had fluoridation approved by their local boards of health.

Although sodium fluoride is most commonly used in water fluoridation, sodium fluorosilicate is much cheaper and has proven to be just as effective. At any rate, the yearly cost of adding fluorides to public water supplies would not be more than a few cents—from 5 to 14—per person. The exact cost depends on the type of fluoride used, the amount of fluoride already in the water and the size of the community.

Fluoride feeders are of two types. *Solution feeders* deliver a measured quantity of fluoride solution during a specified period. *Dry feeders* deliver a predetermined quantity of solid fluoride material during a given time interval. The choice of a feeder depends on the rate at which fluoride is required. This rate, in turn, is determined by the extent of water consumption and the amount of fluoride present in the untreated water. As a general rule, solution feeders are used for small water sysetms and dry feeders for large ones. In communities in which the water is obtained from several different sources, the use of a number of small solution feeders appears to be more practical and economical than the construction of a central distribution system for fluoride treatment.

A development has been the production of a saturator. In this device the water passes through a bed of crystalline sodium fluoride so that a saturated solution of fluoride can be withdrawn by the feeder.

Two types of dry feeders are suitable for fluoridation: (1) volumetric feeders deliver a measured amount of dry chemical within a certain time period; (2) gravimetric feeders deliver a measured weight of chemical in a given interval of time. Gravimetric feeders are especially adapted to large water supplies and are capable of feeding fluoride for the largest city in this country.

Cost of equipment for adding fluorides to water varies from $500.00 for small communities to several thousand dollars for

larger cities. The equipment has been adapted from machines originally designed for adding other chemicals—such as chlorine —to water.

Special legislative action was taken in 1958, which resulted in Chapter 254 of the Acts of 1958. This Chapter was approved April 11, 1958, and is as follows:

CHAPTER 254

THE COMMONWEALTH OF MASSACHUSETTS

In the Year One Thousand Nine Hundred and Fifty-eight

AN ACT REQUIRING THAT THE WILL OF THE VOTERS BE ASCERTAINED BEFORE ANY PUBLIC WATER SUPPLY SYSTEM IS FLUORIDATED.

Be it enacted by the Senate and House of Representatives in General Court assembled, and by the authority of the same, as follows:

Chapter 40 of the General Laws is hereby amended by inserting after section 41A, inserted by chapter 793 of the acts of 1949, the following section:—*Section 41B.* No public water supply for domestic use in any city, town or district supplying such water which is not being fluoridated prior to September first, nineteen hundred and fifty-eight, shall thereafter be fluoridated by any such city, town or district or combination of two or more towns supplying such water jointly unless the will of the voters of such city, town, or district, or the towns being supplied such water by such combination of towns is first ascertained as herein provided. The board of water commissioners or other officers performing like duties may require that the following question be placed upon the official ballot to be used at the next regular municipal election or for the election of town officers at the next annual town meeting or meetings:—"Shall the public water supply for domestic use in (this city) (this town) (the towns of and), be fluoridated?", or in such district may require that the following question be placed before the next annual meeting of the inhabitants of the district:—"Shall the public water supply for domestic use in this district be fluoridated?". If a majority of the votes in answer to said question is

in the affirmative, it shall be deemed and taken to be the will of the voters of the said city, town or towns, or district that the public water supply for domestic use shall be fluoridated, and if a majority of said votes is in the negative, it shall be deemed and taken to be the will of said voters that such supply shall not be fluoridated.

Approved April 11, 1958

The problem which arises then in the field of water-works operation is "Is it an engineering possibility to add fluoride compounds to a public water supply to produce a concentration of 1.0 ppm without mechanical difficulties other than those encountered in normal operation?"

This paper will discuss the fluoride installations in the northeastern area of Massachusetts with respect to the type of equipment, fluoride compound employed, and operation of the fluoride installation.

Description of Installations

The fluoride installation for the *Danvers-Middleton* supply is the oldest public water supply installation in Massachusetts. Fluoridation was started on June 6, 1951, and the method of application used was dry-feed sodium silicofluoride. The sources of supply are Middleton Pond, Swan Pond and Emerson Brook, and at the present time there are approximately 6,000 services in the two communities with a monthly pumping rate of 56 mil. gal. per month. The initial cost of equipment approached $5,000, but chemical cost for yearly operation is at the rate of 8¢ per lb. (10,000 lb. per year are needed). One of the chief problems involved in dry-feed application is the fact that shear pins break when the powder is packed too tightly, or when paper gets into the machine. One complaint which was made during the first few months of the application of fluorides had to do with tastes. Oddly enough, these complaints continued even when the machine was stopped, due to a slight mechanical failure.

Salem-Beverly

The application of fluorides started on December 1, 1952, with a dry-feed machine, using sodium silicofluoride at the rate of 7.25 lb. of fluoride ion per mil. gal. The average daily flow

during 1958 was 7.54 mgd. The type of equipment used is a Wallace-Tiernan type A-625, volumetric, which is controlled by a Foxboro conductivity-difference instrument. No comments pro or con have been reported relative to the application of fluorides in either community. They have experienced little serious operating difficulty, although there has been some corrosion in the mixing apparatus. However, this part is easily replaced. They have also installed an electrical mixer, as sodium silicofluoride dissolves slowly. In a future installation they would propose to use a much larger dissolver and provide electrical mixing. They discharge directly into a large reservoir from the filter plant, so that there is no possibility of depositing undissolved chemical in any part of the water mains, which might be flushed out later. There has been virtually no trouble with the conductivity-difference equipment. About every two years the instruments require new electronic tubes. Other than this it has functioned very well.

They believe that records from their conductivity charts and those of actual quantity of chemical added are far superior to the chemical analysis for fluoride.

North Andover

The town started fluorides on August 20, 1953, using a saturator and sodium-fluoride crystals (98%) for the Lake Cochichewick supply. During the 1958 town meeting, some agitation was brought forth which caused the repeal of fluoridation as of March 4, 1958.

Concord—Kalmia Woods Development

The application of fluorides started in 1953, using a sodium-fluoride crystal, type F 98%, with a saturator and a Treet-O-Unit (a hydraulic drive unit coupled with a Hersey compound meter.) There are approximately 125 services in this development, the initial fluoride installation cost being 1,465. The maintenance of the unit is approximately $50. per year, and the fluoride cost, $37.50. There are at the present time no opposition to the application of fluorides in the development and no operating difficulties. Fluoridation was originally started when this District had its own water-supply system. Later the wells were abandoned and connection was made to the municipal water-supply system.

Topsfield

The application of fluorides was started December 29, 1953, using a saturator. There are approximately 585 services, the source of supply being 30 wells of tubular construction 2½ in. in diameter. The initial installation cost of the unit was approximately $1,200, but this figure included a new floor for the pumping station. There has been some difficulty with plastic heads and tubing. During the early application of fluorides, there were some complaints relative to tastes, but at the present time no complaints are being received.

Essex

The application of fluorides started in May, 1955, using a saturator. The source of supply consists of two gravel-packed wells with a monthly pumping rate of approximately 4.0 mil. gal, and there are approximately 800 services. At the present time, the unit is not in operation. The saturator consisted of a cast-iron tank with a polyethylene lining. Due to humid conditions in the pumping station, the cast-iron container has corroded and is now being replaced with a stainless steel tank. The initial cost of the installation was approximately $840. There are no complaints received by the Water Department, but occasionally they are blamed for rusting and corrosion of galvanized pipes.

Hamilton

Fluoridation was started in February, 1956, using three saturators, one each for the gravel-packed wells at Bridge Street and School Street, and the Patton well. There are 1,500 services, and the installations at the Bridge Street and School Street wells cost approximately $1,800. The Patton gravel-packed well installation was $678. There have been no adverse comments relative to the addition of fluorides in the community, and the only mechanical difficulty encountered was that a diaphragm had to be replaced on one of the feeders. There have been relatively very few experiences with respect to mechanical equipment at this installation.

Winchester

The addition of fluorides started in February, 1957, using saturators with sodium-fluoride crystals. These saturators, which

are hydraulically operated, are of the Treet-O-Unit type and are coupled with a Hersey compound meter. At the present time there are approximately 5,200 services, and the original fluoride installation cost was $5,926.25. The superintendent reports that there have been no adverse comments made to the water department. At the present time, the pneumatic feed-control equipment is not working, and they are experiencing difficulty with the hydraulic system of layout and controls.

Wilmington

Although Wilmington voted the addition of fluorides in 1957, the supply was fluoridated on-and-off until the beginning of 1959, and, at such time fluorides were added continuously. Fluorides are added by means of a saturator employing sodium-fluoride crystals. The sources of water supply are the Brown's Crossing well fields and Barrows well field. There are approximately 3,000 services, and the original installation cost for both stations was $209.30. There has been considerable difficulty with scoring of the pistons in the unit at the Brown's Crossing station, which has resulted in periods when no fluorides were being added to the system from that pumping station. There is considerable agitation on the part of some of the residents in the community, with the result that an unfluoridated tap in the pumping station is made available to the residents of the community.

Reading

The addition of fluorides in Reading started in November, 1957, and continued until October 5, 1959, when it was voted out by referendum ballot. The fluoride addition was by means of sodium-fluoride crystals in a saturator, located at the main pumping station. The application of fluorides to the Reading supply has been a very controversial subject since its inauguration, and complaints have been relative to "blue water." During the balloting, 1,300 out of 2,000 voters cast their ballots against the addition of fluorides. There are 6,000 registered voters in the town.

Andover

The addition of fluorides started in February, 1958, with the use of sodium-fluoride crystals in a stainless-steel saturator.

The average monthly pumping rate is 1½ to 2 mgd. The initial costs were $3,000, and there are approximately 5,000 services. The main source of water supply is Haggett's Pond Reservoir, with two gravel-packed wells in Ballardvale. Lime-treated water is used for make-up water in the saturator. Apparently, the calcium ion precipitates as an insoluble calcium fluoride, coating over the supporting sand in the saturator. This coating collects in the pumps, tubing and valves of the feeding equipment. One innovation started at these installations is the replacement of the gravel in the bottom of the saturator with a course chicken grit obtained from one of the nearby quarries. This grit is very uniform in size distribution and has worked exceptionally well, eliminating the frequent clogging in the saturator. There is apparently some unorganized objection to fluorides in the community, and it is reported that many residents use an unfluoridated tap.

Lynnfield Center Water District

The addition of fluorides to the Lynnfield Center Water District supply was voted in 1958 and commenced in January, 1959. The equipment employed is a saturator type with a Chronoflo rate-of-control unit. There are approximately 1,425 services fed from a 24-in. gravel-packed well and 65 2½-in. tubular wells. The average daily pumping rate is 250,000 gal. per day. The Lynnfield Center Water District is one of two water systems in town. The Lynnfield Water District obtains its water from the Metropolitan District Commission and does not add fluorides.

Within the Lynnfield Center Water District, the feeling toward the addition of fluorides is very evenly divided. A referendum in October of 1959 resulted in a vote of 204 in favor, and 201 opposed. However, there are no objectionable comments on the quality of the water. There was one complaint this past summer from a consumer with a possible reference to death of fish in a goldfish pond. However, an investigation of this matter disclosed that the fish in question were in an extremely shallow pool, and the temperature of the water was in the high eighties. Apparently there was very little oxygen left in the water, or the fish became parboiled to a degree.

General Considerations

Corrosion

In response to many requests for an investigation relative to possible corrosion of the distribution system upon fluoride addition, a study was carried out by Joseph A. McCarthy, Chief of the Lawrence Experiment Station, Massachusetts Department of Public Health. The results of this study were written up in the June, 1959, issue of "Sanitalk." The conclusion reached in this study was that the results were definitely indicative that added fluoride has no effect on the corrosion of common household metals.

Tuberculation

In a panel discussion on the experience of applying fluorides, which appeared in the October, 1957, issue of the Journal of the American Water Works Association, it was stated that the tubercles adhered tightly to cast-iron pipe, and it was necessary to scrape the pipe forcibly with a metal tool to collect a sample for analysis. Hence, it is believed that the encrustment would not be removed by turbulent water flow. A 2-inch square of the cast-iron pipe was thoroughly cleaned of all tuberculations down to the base metal with a buffing machine. The metal was shaved, and a representative 1-gram sample of the shavings was analyzed for fluoride content by the distillation method. No fluoride was found. A possible explanation for the presence of fluoride in the encrustment mentioned above from other installations is that it was deposited from the raw water during the period of tubercle growth, the raw water having a small fluoride content. The flowing water in the mains neither removes the hardened tubercles nor dissolves the entrapped fluorides significantly.

Reagents for Fluoride Determination

The policy of the Massachusetts Department of Public Health requires daily tests for fluoride content to be made on public water supplies where a fluoridation program is in effect. Until the first of July, 1959, the Division of Sanitary Engineering had supplied the communities with the necessary laboratory glassware and supplies, because no practical method was commercially available for the purpose. With the growth of the fluoridation

program in the Commonwealth, this has resulted in a substantial burden on the funds and the laboratory personnel available to the Division.

A new type of commercially available apparatus for making fluoride tests has been examined by the Lawrence Experiment Station and found satisfactory for use by water-works personnel. The apparatus referred to is available from the Hach Chemical Co. of Ames, Iowa, and the Division is informed that the price is about $165.00, which includes a year's supply of test chemical. It has therefore been requested that all fluoridating communities purchase apparatus which will enable them to make the necessary fluoride determinations.

Distribution System

Samples for fluoride determination are normally taken at the pumping station and representative points on the distribution system. The question often asked is whether fluorides dissipate throughout the system so that the content is reduced, or whether fluoride concentrates in the dead ends of the system. It has been our experience that the fluoride determinations at the pumping station and out on the distribution system are usually relatively much the same. Thus we have no reason to believe that fluorides are concentrated in the dead ends of the distribution system, nor do they tend to dissipate.

Summary

The application of fluorides to the public water supply in northeastern Massachusetts started with the Danvers installation in 1951, and since that time 14 communities in the northeast area have had experiences with its addition. Although I have discussed some of the experiences in the application of fluorides to public water supplies, time does not permit me to go into complete details with each community. I think that it is safe to conclude, however, that the application of fluoride compounds to public water supplies is feasible from an engineering standpoint. Certainly the equipment employed is of such a design that, within the limits of accuracy, a concentration of 1.0 milligram per liter can be maintained.

There have been no major mechanical failures other than

those of so-called normal operation and over which no one has control, such as might be expected from any mechanical piece of equipment. Additionally, our records show that with the acceptance of the water-works superintendent, fluoride compounds can be added with no great difficulty. Certainly from the engineering standpoint it must be concluded that fluoride compounds can be added in a scientifically controlled fashion, mechanically and practically, when it is so voted by a referendum ballot, the annual cost being approximately 8 cents per capita.

Discussion

Angelo Iantosca*: The experiences in two western Massachusetts communities where fluoridation has been abandoned may be of interest in connection with the subject paper.

In the larger community, operating problems encountered in the beginning were quickly overcome and a proper and constant fluoride level was attained. However, the opponents of fluoridation in the community brought legal action and were able to obtain a temporary cessation of the program pending a court decision. Fluoridation was subsequently resumed after a favorable finding by the court, only to be discarded by a referendum of the voters.

It should be emphasized that the application and control of the chemical was quite successful in the hands of capable and coöperative water-department personnel.

It must be concluded that the program was abandoned because of unfavorable public opinion, which apparently existed before fluoridation was introduced and which finally culminated in its abandonment.

In the case of the smaller of the communities, the program was initiated with little opposition from the residents. In the beginning some minor difficulties were experienced, mainly because of hardness in the water supply. These difficulties were apparently made known, and considerable misinterpretation by the public and some distorted publicity resulted. It is believed that this incident resulted in undue public alarm, followed by a referendum which halted fluoridation.

This experience seems to indicate that public acceptance of

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fluoridation may require that water-supply officials keep the consumers properly informed of the fact that fluoridation is an accepted engineering procedure, which is carried on under competent supervision and control. While minor problems may arise as they did here, it is felt that they can be overcome readily with the coöperation of all parties involved.

PAUL T. ANDERSON*: The application of fluorides to public water supplies in the Southeastern Health District has been carried out very satisfactorily by the water departments involved.

The first installation was in the Seekonk Water District in January of 1952. The apparatus consisted of a slurry of sodium silicofluoride, applied by a positive displacement pump. This apparatus was later replaced by a saturator. With the addition of another pumping station, similar apparatus was installed. These saturators were made of 55-gal. drums that were neoprene-coated. Some difficulty was experienced with the neoprene coating separating from the metal, and in early 1959 these units were replaced with stainless steel barrels. The application of fluorides has been continuous and satisfactory, except for minor mechanical failures causing short-term interruptions and the failure of a main pump, necessitating shutting off fluoride apparatus from this source for a period, due to lack of electrical connections.

The Hingham Water Co., serving the towns of Hingham and Hull, uses both dry-feed and saturator-type apparatus. The application of fluorides here has been very satisfactory ever since its inauguration.

The Scituate Water Department started out using a two-barrel system, where they made up the saturated fluoride solution in one barrel and then siphoned it into another barrel, from which it was pumped into the system by a positive displacement pump. This system was unwieldy and is gradually being replaced by saturators.

The Sharon Water Department started out with dry-feed apparatus, which gave considerable difficulty, and after a time this apparatus was replaced with saturators. The only difficulties

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that have been experienced since the change have been minor mechanical ones.

The Cohasset Water Department started out with stainless-steel saturators, and the application of fluorides has been most satisfactory since its inauguration.

The town of Sudbury has voted approval of fluoridation. No apparatus has yet been installed, pending approval of the plans by the Department of Public Health.

In general, it would seem that, even though some water superintendents have not been wholly in favor of this added facet to their work, the application of fluorides to the public water supplies in this District has been very satisfactory. The only troubles have been minor mechanical ones with the equipment, which tended to shut off the application of fluorides for short periods of time. It has been found that in the use of saturators, a granular type of chemical is more satisfactory than the fine powder, due to the fact that the granules go into solution more readily.

OBSERVATIONS ON WATER SUPPLIES IN EGYPT

BY J. CARRELL MORRIS*

[*Read December 17, 1959.*]

Egypt, as everyone knows, is the land of the Nile, one of the world's two longest rivers, which provides virtually the sole surface-water supply for the twenty-four million inhabitants of that ancient land. One of the main branches, the white Nile, flows generally northward from Lake Victoria in Central Africa and has a relatively uniform year-round yield of 30,000 to 50,000 cu. ft. per second. The other main branch, the Blue Nile, descends from the Ethiopian highlands to the east to join the White Nile at Khartoum in the Sudan. The volume of the Blue Nile is highly variable, ranging from less than 7000 cu. ft. per second dry flow to more than 200,000 cu. ft. per second in flood flow. Through the northern Sudan and Egypt the conjoined rivers flow for more than 1600 miles to the Mediterranean without influx from a single tributary. Over 700 miles of this watercourse lies in Egypt. From the first cataract at Aswan to the sea the drop is only one in thirteen thousand or about 250 feet for these last 600 miles. At Cairo, just before the river splits to form the Delta, the mean annual flow is 80,000 to 110,000 cu. ft. per second, ranging from somewhat more than twice this for the four months of flood to somewhat less than half for the eight months of dry flow.

Along the Nile from Aswan to Cairo the cultivated, inhabited land ranges from one to twenty miles in width, depending on the topography. Just north of Cairo the Nile begins to divide into its many mouths forming the fan-shaped Nile Delta, criss-crossed by canals and irrigation ditches. In the triangular Delta area, about 150 miles on a side with an area about 1/5 of that of New York State, live 90% or more of the 24 million Egyptians.

At Aswan in upper Egypt there still exists one of the Nilometers used more than three thousand years ago to measure

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the heights of the Nile floods. This is a rock stairway cut down to the river in the Syene granite of the Elephantine Isle with gauge marks chiselled on the sides. Other similar gauges of later dates are found up and down the Nile, one of the most noted being on the Island of Roda at Cairo, where continuous flood records have been kept for the past 1200 years. Annual taxation rates were based on the flood heights determined by this and other gauges in operation in ancient times, for high floods meant good crops.

General Survey of Egyptian Supplies

Yousef[1] has recently summarized the status of public water supplies in Egypt. According to his account about 80% of the population was supplied with potable water in April, 1958, and this was expected to increase to 90% by the end of 1959. The southern part of the Delta and upper Egypt along the Nile can be supplied by untreated ground water safely and economically, he states, while in the remainder of Egypt treated surface water supplies are commonly used. Most of this ground water probably comes by infiltration from the Nile or its branches, although there are currently some developments in the desert region between Cairo and Alexandria that are tapping very deep water, about 1500 to 2000 feet below surface, I believe.

Yousef states that there are about fourteen hundred rural ground-water supplies, serving about eight million people. These consist of deep wells with centrifugal or bore-hole pumps, storage tanks and distribution systems, each supplying a group of small villages. Besides these installations, there are sixty municipal waterworks that supply ground water to larger towns. A typical facility, given by Yousef, is the Mit Ghamr pumping station, which has a capacity of seven hundred fifty thousand gallons a day and serves thirty thousand people, the rate of consumption being about 25 gallons per capita per day, the present mean rate of consumption for small towns in Egypt. The city of Cairo has also been attempting recently to augment its surface-water supplies with ground water from wells near the Nile; these are to be used primarily to provide backwash water for the rapid sand

[1]Yousef H. Yousef, "The Status of Water Supply in Egypt." Proceedings of the Waterworks Operation Training Course, Alexandria, U.A.R., 24 April-11 May, 1958. Regional Office for the Eastern Mediterranean, World Health Organization.

filters at the treatment plant, releasing an additional 10% of purified water for municipal consumption.

Again according to Yousef there are over forty municipal installations using the Nile and its branching canals as the source of raw surface water. As an example he cites the Mansourah waterworks, which treats 3.6 million gallons a day for one hundred twenty thousand consumers, a daily rate of consumption of about 30 gallons per capita. There are also six plants in the large municipal cities, like Cairo and Alexandria, which provide treated Nile water in daily amounts running up to 65 gallons per capita.

Recently six centralized surface-water projects have been undertaken to supply the more than five million inhabitants of the rural areas of Northern Delta and Fayoum provinces. Each of these projects provides 7 to 12 million gallons of treated water a day at a rate of about 10 gallons per capita. One of these, the Sherbin waterworks, is described by Yousef. Water is taken from four intake points along the Nile and lifted by centrifugal pumps to the treatment plant. Alum is added at a dosage ranging from 5 to 150 milligrams per liter, depending on the turbidity of the raw water. Coagulation and settling take place in two circular clariflocculators with a capacity of about one million gallons. The water then undergoes rapid sand filtration; there are twelve filters each having a working discharge of 80,000 gallons per hour. Chloramine at a dosage of 4 to 8 mg per liter is used for disinfection, giving residual chlorine of at least one mg per liter throughout the distribution system, which has a total length of about 600 miles. This water is supplied free of charge to encourage use of treated water instead of the contaminated water from the canals.

Characteristics of Nile Water

The major problem in the treatment of Nile water is its highly variable and periodically very intense turbidity. At times of low water flow, from December to July, the river at Cairo contains from 50 to 80 mg per liter of suspended matter, but during the flood period, reaching its peak in September, the suspended matter increases to over 4000 mg per liter (8000 to 10,000 turbidity units). In addition, algae are a problem at certain

seasons; the troubles occur during the low water periods, for high turbidity prevents the growth of algae during the flood stages. From February to April filter-clogging diatoms and filamentous green algae often become troublesome. In June and July blue-green algae, such as anabaena, multiply and give rise to odors and muddy tastes. Other chemical characteristics are presented in Table 1.

TABLE 1—CHEMICAL CHARACTERISTICS OF NILE RIVER WATER AT CAIRO

Property	Concentration, mg. per liter	
	Low water	Flood
Total dissolved salts	180 — 220	140
Alkalinity	100 — 150	80 — 120
Sodium chloride	50 — 60	—
Hardness	ca 100	—
pH value	8	8

Bacteriologically the Nile is rather heavily contaminated; the raw-water count of *E. coli* may reach 200 per c.c. in June and July just before the flood; during most of the year it is considerably lower.

TREATMENT OF NILE WATER AT CAIRO

The Rod el Farag works treating water for the city of Cairo has a capacity of approximately one hundred million gallons a day. Demand has increased four-fold over the past twenty years and is continuing to rise at a rapid rate. During the summer of 1959 there were numerous periods of water shortage in the city and a number of breaks in mains caused by increased pressures as attempts were made to maintain flow to distant points of the distribution system. Additional major installations are needed.

The Rod el Farag works has two sections each treating about half the supply. In the older south section, the incoming water after dosing with alum or, when the turbidity is high, with both lime and alum in the ratio of 1:2, passes to four square Dorr clarifiers, in parallel, each with a capacity of 1.7 million gallons. These were installed between 1928 and 1937. From the clarifiers the water goes to nine rectangular sedimentation basins, also in parallel, with capacities of one million gallons

each. The sedimentation basins are the oldest units of the works, having been built between 1910 and 1923. The two sets of units provide a total of seven hours of sedimentation time.

At the north section, where the raw water receives the same alum treatment as that at the south section, there are: two Patterson clarifiers installed in 1947, each of 1.2 million gallon capacity, fitted with flocculators; three Accelator-type clarifiers, one installed in 1951 with a rating of 0.3 million gallons per hour, the other two built in 1953-4 having together with the next a combined capacity of 1.1 million gallons per hour; and a Cyclazur-type clarifier, similar to a Dorr-Oliver Clari-flocculator, also built during 1953-54. *E. coli* counts are reduced about 80% during sedimentation.

From both sections the water passes to the rapid sand filters, 116 in number, of which 72 are Patterson, 32 are Jewell and 12 are Degrémont filters. The Jewell filters were installed in 1910-1912; groups of Patterson filters have been installed at several times between 1928 and now, the last group of 24 having been placed in operation in 1954; the Degrémont filters were installed in 1950-51. The Jewell and Patterson filters are operated with graded sand and gravel beds totalling 46 inches in depth; the Degrémont beds are all sand, 16 inches deep, 13 to 18 mesh. The filtering rate is 100 meters per day (1.7 gal. per square foot per minute). Backwashing ordinarily is done once a day, but at times of high algae content the filters must be washed 3 or 4 times a day. The Jewell filters undergo mechanical surface agitation prior to backwash; the Patterson filters are operated with two minutes of air agitation followed by ten minutes of backwash; in the Degrémont filters air blast and backwash occur simultaneously.

The filtered water, in which the *E. coli* count has been reduced to one per ml. or less, flows into underground storage reservoirs with a capacity of three million gallons. The water is dosed with 0.6 mg per liter of chlorine as it enters the reservoirs. Daily bacteriological testing follows British technique. If 25 or 50 ml. samples give positive results when cultured in MacKonkey broth, the chlorine dose is increased.

Control and Administation of Water Supplies

Because Egypt has a centralized form of government, administration, control and operation of water-supply facilities differ from the practice in the United States in that these functions are national ones. Waterworks in rural areas, small towns and municipalities are constructed and operated directly by the national Ministry of Municipal and Rural Affairs. In addition the Ministry has its own chemical and bacteriological laboratories, and employs the personnel for control of water quality.

This kind of governmental administration has a considerable advantage in a densely populated, predominantly rural country like Egypt, for water supplies can be developed according to regional needs and on that scale which is most economical for operation and maintenance. Moreover, plants can be constructed for areas of greatest need, rather than only where local wealth is great enough to finance installations.

Administration and control of water supplies in the half-dozen large municipal cities of Egypt is different, although still on a national basis. In the cities, construction and operation of waterworks and distribution systems is the responsibility of the National Ministry of Public Works, while supervision of the sanitary quality of the water supplies is entrusted to the Ministry of Public Health.

The Aswan Dams

There are at the present time a number of dams and barrages used for controlling the flow and level in the Nile River. These have permitted a change from flood irrigation to perennial irrigation throughout the Delta and for about half the distance from Cairo to Aswan along the Nile. With perennial irrigation, three crops a year can be grown, rather than the one crop annually when flood irrigation is used. The productivity of the land is therefore increased enormously under perennial irrigation.

One of the most important of these structures for control of the Nile is the Aswan Dam, situated just south of the municipality of Aswan. This should not be confused with the controversial and as yet unconstructed Aswan High Dam, the site for which is several miles farther upstream to the south.

The Aswan Dam was constructed initially in 1902, but has

twice been increased in height so as to provide greater storage capacity. The present dam is about 2000 yards in length and stores two million acre-feet of water in a lake 100 miles long. However, this volume is only a small fraction of the annual flood flow; so the present Aswan Dam does not provide multi-year storage of water.

Multi-year storage will be achieved with the construction of the High Dam. Because this dam will provide relatively uniform flow in the Nile throughout the year, it will allow additional lands to be brought under continuous cultivation. Moreover, with an assured year-round discharge of water, power development has become practicable at the old Aswan Dam as well as in conjunction with the High Dam. A million-kilowatt power station has been under construction at the Aswan Dam for some time and was scheduled to be completed by the end of 1959.

Plans and Problems

Although Egypt as a whole must certainly be classed with the arid lands, an absolute shortage of water is not an immediate problem for the inhabited and cultivated areas of the country. The annual flow of the Nile is sufficient to provide 100 gallons per capita per day for a population of 30 million plus 8 to 9 ft. of water annually for the presently irrigated lands, comprising about 70 million acres. Were this water distributed evenly throughout the year, it is estimated that several million additional acres of land could be brought under 3-crop, year-round irrigation. This is one of the objectives underlying the erection of the High Dam at Aswan.

The current, more crucial need is adequate development and treatment of the water for domestic purposes, to provide safe water supplies throughout the country. Up to now most of the installations have been package plants imported from Europe or the United States, or plants designed to be appropriate for the types of waters and the conditions of treatment encountered in those temperate areas. It is the conviction of some Egyptian experts that many of these have been overdesigned. They feel that if there were available appropriate basic data for design adapted to Egyptian waters and conditions, one-fourth

to one-third of the cost of construction and operation of water treatment plants might be saved. Thus, at the present time there is great interest in research and development on methods of water treatment suitable for Egyptian conditions and making use of materials available within the country.

On July 26, 1959, there was officially opened at Alexandria the Sanitary Engineering Research Centre for the conduct of chemical, biological and engineering studies on Egyptian water supplies and their treatment, together with studies on waste treatment and disposal. This institute, which is an independent budgetary unit of Alexandria University, has been modeled after our own Lawrence Experiment Station, in design as well as in function. With the assistance of the World Health Organization, consultants in various areas of Sanitary Engineering are being brought in to assist in the initiation of programs of research, and staff members are being sent to Europe and the United States to learn techniques and exchange ideas with other universities and research institutions.

It is believed that this is the first research institute of Sanitary Engineering outside of the United States and western Europe and is a mark of the forward-looking concern with which Egyptians regard problems of water supply and treatment.

STUDY OF DISTRIBUTION SYSTEM IN SALEM, MASSACHUSETTS

BY NEAL B. MITCHELL*

[*Read at Superintendents' Session, Jan. 21, 1960.*]

To appreciate the need for proposed improvements, a brief review of the history of the water works in Salem is helpful. Until the year 1796 there is no record of any public water supply. At that time, however, there was formed The Salem Aqueduct Company. This company built a reservoir 10 feet deep and 24 feet square on Gallows Hill. The supply mains were pine logs of 3-inch bore. In a few years the Company built an additional reservoir of 22,000-gallon capacity on Sewall Street in the downtown area, and replaced the original logs with logs of 5-inch bore.

It was not until 1834 that a 6-inch iron pipe, the first used by this company, was laid in Essex Street. At this time it became necessary for water takers to affix pumps to their branches, to enable them to get any water. During 1839 an iron pipe was laid from Gallows Hill to the main pipe in the downtown area, and in 1849 a new pipe was laid through Union Street to the Steam Cotton Mills in South Salem, which were authorized to draw water during the night. Most industries were prohibited from drawing water at any time.

By the end of 1851 they had laid more iron pipe and built a new reservoir to hold 652,000 gallons. In 1852 iron pipe was laid to replace all logs. There was no further shortage of water until 1859, when the 12-inch pipe was extended to Spring Pond, and a 12-inch gate was affixed to graduate the use of water which, the Directors said, "we have never as yet had occasion to raise beyond 1-inch." At this time the company had 40 miles of pipe and branches, and had 3600 water takers, while their reservoirs were capable of holding 1,100,000 gallons, not including Spring Pond.

Water shortage existed again in 1863, when it became necessary to make a connection to Browns Pond, situated over ½ mile

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above Spring Pond; to lay a 16-inch main to the head of Federal Street, and many other new pipes. With a capacity of 600,000 gallons per day there was still much shortage. Not a house existed where water flowed regularly on the second floor; out of 170 bath tubs, 123 had pumps; only 2 fire hydrants in the city were available, and they would not throw water to the second story; a fire engine on a downtown street could interrupt the supply for the whole city.

Right after the Civil War the city started to build its own water works, to obtain water from Wenham Pond. It built Chipman Hill reservoir and obtained a steam pumping engine, "the same size and character as that used in Charlestown." The total head and capacity of the Charlestown system, it would seem, were identical to the total head and capacity of the proposed Salem system,—or were they? The pipe obtained for the 30-inch force main and the 20-inch supply main was found to be deficient in weight. Some pipes were only ⅓ the required thickness. Most of the pipe was laid before the deficiency was discovered, but some were replaced with new pipe. Later, as the line kept breaking, more new pipe was laid in this line.

Sheet wrought-iron cement-lined pipe was used in the distribution system. The lengths were connected by sleeves of sheet iron around the outside of each joint, between which and the iron of the pipe is a 1-inch space, which is filled with rich cement, making a joint that is perfectly water-tight. This kind of pipe has been so extensively used and is so well known, that nothing need here be said in regard to its durability and efficiency as a water conductor. It has been successfully used under pressures much exceeding ours.

On Christmas morning in 1868 water was let into the service pipes. The water works cost double the first estimate but involved much more work than was included in the original plan. During the 1880's there were many leaks in the sheet-iron cement-lined pipes.

About 1890 a new 30-inch supply pipe was laid through Danvers. This increased the pressure but also increased the leaks. A program of replacing all old wrought-iron pipe with new cast-iron pipe was started.

A water shortage in 1893 made it necessary to construct

Longham Basin, which increased the storage capacity by 55 million gallons. This was intended to give only temporary relief. By 1913 it was necessary to recommend that a new pipeline through Beverly over Kernwood Bridge, or a large standpipe, be built on the west side of the city, to be used in case the 30-inch main through Danvers should be out of order, as it has been on many occasions.

During the big Salem fire in 1914 that destroyed 1800 buildings on 80 streets, the water pressure was observed to drop from 42 pounds per square inch to 10 pounds per square inch. Two 5-mgd pumps were in continuous operation for 55 hours. In 1916 two new steam pumps of 20 million gallon per day capacity were installed in place of the old ones. Folly Hill reservoir of 10 million gallons capacity was built. A new 36-inch supply pipeline was constructed from Folly Hill reservoir. This gave much greater pressure and volume throughout the city.

It was noted that there was much waste of water with the higher pressure and that meters would be necessary. By 1917 all the old sheet-iron pipe had been replaced with new cast-iron pipe.

In the following years an increasing amount of river water was pumped into the lake, with a corresponding decrease in the quality of the water. To improve the quality, the new filter plant went into operation in 1935. It is understood that Folly Hill reservoir was cleaned, but the supply mains and the distribution system were not cleaned or properly flushed.

During the year 1950 it was necessary to reconstruct the pumping station and install new electrically operated pumps. The continual shortage of water during every dry year made necessary, in 1955, the construction of Putnamville Storage Reservoir with a capacity of 1500 million gallons, to be used for maintaining the level of Wenham Lake. At this time the 16-inch main in Fort Avenue was cleaned and cement-lined, increasing its capacity to deliver water by 50%.

With adequate supply, pumping capacity, and treatment facilities, the city received numerous complaints of low pressure in the newly developed Highland Avenue section, and of very dirty water in many other sections during peak summer flow. It was only necessary to use a hydrant, anywhere in the distribu-

tion system, and that section would be flooded with dirty water. Attempts at flushing sometimes gave temporary relief but frequently stirred up greater areas of dirty water.

It was believed that much sediment was being drawn from the large supply mains, and no amount of flushing from hydrants could be expected to drag them clean. Under these conditions it was guessed that at least 800 tons of incrustation and silt existed in our 100 miles of pipe. With this in mind and without the knowledge of actual flow conditions it was assumed that, at peak demand, silt would be carried along the supply mains into the distribution system. Thus it was recommended that these supply mains be cleaned and cement-lined, as a first step towards supplying clean water at all times throughout the city. Such cleaning and lining were estimated (1959) to cost about $550,000. It would then be necessary to clean and line all the large feeder mains in the city proper, which was estimated to cost another $150,000. After all this work had been done, it was planned to flush all the smaller mains (about 80 miles) until clean water would be had throughout the city.

Regarding the low water pressure along Highland Avenue, it was planned to lay a 16-inch booster main up the avenue and construct a 300,000-gallon tank on a hill near the far end of the avenue. This work would cost about another $150,000, making the total proposed work come to about $850,000. With engineering and inspection of construction added the total would be over $900,000.

Then came the hot summer of 1959, and the headlines in the local newspaper read as follows:

"Dirty Water Ires South Salem.
Protests Go Unheeded for Years.
Hundreds of South Salem Houses With Dirty Water.
It Has Long Plagued Residents of a Wide Area During Heat Waves.
Protests to City Officials Resulted in only Temporary Relief.
Only Token Relief During Past 12 Years.
Coffee-color Wash Stirs Protest from Housewives.
A Recurrence of a Long-standing Nuisance,—Only Worse."

After this splurge of adverse publicity, the city government decided to do something, and requested the Mayor to seek an appropriation to finance the cleaning and cement-lining of the

large supply mains, thereby guaranteeing the delivery of clean water, *at every tap in the city*. This, of course, could not be done, and since our original plans for improvements were based on assumptions, it was decided to discuss this more thoroughly with the City Council.

On June 30, 1959, a conference was held with the City Council, at which time the present condition of the entire system and the particular condition of dirty water and low pressure were explained in detail. The many ways by which relief might be obtained were also explained. It was made very clear that none of these should be attempted until it had been determined how the present system functions at all times—that is: which are the pipelines contributing dirty water and which are not; where are the weak and where are the strong sections; what is the best way to reinforce the weak sections; and what is the best way to hold the pressure in the high-level area of Highland Avenue? This, of course, can only be done by a complete investigation of the entire distribution system. The previously suggested solution to the problem was, by necessity, only considered opinions based on average assumptions, and otherwise known as a "guesstamation".

The best method of solution and a more accurate estimate of its cost can only be obtained after a detailed investigation of the various problems involved. This would include the investigation of the various flow characteristics of the entire distribution system, from the pumping station at Wenham Lake, through Danvers and through Beverly, to the thousands of consumers in Salem. They were advised that an investment in sound, practical engineering advice would result in the economical solution of our water-transportation problems.

An investigation of this sort, with its recommendations and detailed estimate of the cost of improvements, would require several months by men expert in such work. The generally recognized organization for such work is the Pitometer Associates of New York. These men make investigations of an existing system, then recommend improvements in the order of their importance. They do not design or supervise construction. For this reason the Pitometer Associates recommend what is best for the system, without any influencing interests in any particular

type of construction. It can be said that these people chart a course of action that we must follow, to take us, in the most economical way, out of the low pressure and dirty water predicament into the high pressure and clean water condition we desire.

We obtained from the Pitometer Associates a proposal for making investigations and flow measurements of the water-distribution system of Salem, and also for making a water-waste survey. The city government immediately provided the amount of the fee, and this work was started on Aug. 1, 1959. A series of investigations was carried out, to determine the condition of the existing distribution system and how it functioned. These included pump-efficiency tests, 24-hour gaugings of the flow in the principal feeders by photo-recording pitometers, loss-of-head, fire-flow and pressure tests.

The two centrifugal pumping units ordinarily used in the Salem pumping station were tested for wire-to-water efficiency and found to be operating under conditions quite different from those for which they were designed.

Flow gaugings were made to determine how the principal feeders were functioning, whether any of them were over- or under-loaded. In general, all the feeders are under-loaded rather than overloaded. The only main that is carrying even a fair amount of its normal capacity is the 30-inch line from Salem Road, Beverly, to the Folly Hill reservoir, and the maximum velocity registered on it was below 3 feet per second.

The other transmission lines, the 20-inch, 30-inch, and 36-inch, all show maximum water velocities close to 1 foot per second. In the city proper no maximum velocities reached 2 feet per second, and since velocities of 4 to 6 feet per second are normal design practice for large mains, it can be appreciated that the Salem feeders are working well below their theoretical capacity.

Loss-of-head tests were made to determine the present carrying capacity of pipes, so that comparisons may be made with that of new pipes of the same or different diameters, and to find out what effect the water supply used has had on the internal surfaces of the pipes in the distribution system. These tests on the feeder mains were made by measuring the water velocities by

pitometer, while pressures were obtained by using recording gauges calibrated after each test.

For the 6-inch and 8-inch mains in the distribution system, the "C" factors were obtained by direct loss-of-head measurement between pairs of hydrants connected by ¼-inch hose, the velocity being measured by pitot tube at an opened hydrant downstream from the connected hydrants. The ¼-inch hose was also used in some instances, on 12-inch, 16-inch, and 20-inch mains, but water velocities were measured by pitometer. The type of instruments used and the care exercised in making the tests were such as to insure results which were as accurate as could be expected from any type of field test. In all cases the mains tested proved to have low "C" factors, generally well below those normally to be expected of pipe of the same length of service.

In calipering the inside diameter it was not unusual to find that the tuberculation was reducing normal diameter by as much as 1 inch. The original carrying capacity of the mains in the Salem system has been very seriously reduced. Another way to express the loss in carrying capacity is to say that the 20-inch line through Beverly has less carrying capacity today than a new 14-inch main of the same length would have. A very smoothly lined 24-inch main would have about the same friction loss at various flows as the 36-inch line now has from Folly Hill reservoir to the city. This is a drastic reduction in carrying capacity.

The distribution mains inside the city have "C" factors even lower than those for the transmission mains, and from all observations during the study, while operating gates, running loss-of-head tests and fire-flow tests, it was obvious that the entire piping system has become overloaded with both sediment and tuberculation. While obtaining high-volume discharges from hydrants, large amounts of black and red sediment were flushed out, and even an appreciable amount of stones and tubercles. In some instances "C" values were found below 40, which is equivalent to less than 30% of the pipe's original carrying capacity. The only main in the system found with a "C" factor above 100 was the 16-inch Fort Avenue line that was cleaned and cement-lined in 1955.

Fire-flow tests were made throughout the system, to deter-

mine how much water was available for fire-fighting purposes without reduction of pressure below 20 pounds per square inch. These tests brought out three principal points. The transmission mains are more than adequate to carry the water required for maximum day demand plus maximum fire requirements. This is due to their large diameter in relation to the daily demand, and in spite of their low "C" factor. The fire flows inside the distribution system, away from terminal points of the 30-inch and 36-inch transmission lines, while adequate, were obviously lower than they should be, due to the very low "C" factors that are the rule for practically all piping in the network. In some areas very low fire flows were noted, due to closed gates.

To determine the presence of any abnormal conditions in the system, not accounted for by difference in elevation, a pressure survey was made. Pressures were found to vary from about 20 pounds per square inch to 80 pounds per square inch inside the distribution system. Special tests were made on one afternoon when temperature was 92 degrees, to determine the effect of high rates of water consumption on pressure. In some instances at the points of greatest distance from the source of supply, pressures were found to be as much as 19 pounds per square inch below those usual under normal demand conditions.

The valves and hydrants were found in very bad condition. Many valves were found shut, some broken. Most of the valves operated with difficulty at first, but once closed, they would then operate easily. This indicated that the valves were seldom operated. The hydrants were found in a deplorable condition; only those installed in recent years operated with any ease; the old hydrants had to be forced open and then were difficult to close. Most of the old hydrants had loose foot valves, causing them to chatter when opened or closed, producing very serious water hammer in the system. In many instances open hydrants produced veritable fountains from bonnet, barrel, and nozzles, half drowning the operator and vicinity.

One of the outstanding features of the Salem water distribution system is the heavy tuberculation and sediment that have built up inside the pipes over the years. This was partly due to the soft corrosive water and partly due to the fact that for more than 60 years raw water was pumped into the system

without treatment. For years now no serious attempt has been made at flushing sediment from the mains, with the result that at present slight increases in water velocity during peak-load periods, flow reversals following gate operation, or use of hydrants, etc., cause wide-spread complaints of dirty water. Opening a hydrant produces a stream of almost black sludge for a matter of 10 to 15 minutes, followed by a gradual clearing that may take hours to reach a reasonably clean stream.

It is possible that Folly Hill reservoir is likewise burdened with sediment and, since it has but one compartment, this cannot be remedied without eliminating all storage reserve while cleaning operations are carried out. Folly Hill reservoir is located well to the north and outside the distribution system. A serious break on any of the trunk feeders between the pumping station and the city almost guarantees emptying the reservoir, thus negating the full value of these 10 million gallons of storage when most needed.

There is no storage *inside* the distribution system proper. The various field tests we have made of the existing Salem water-distribution system, plus close study of the records of past operation and performance, bring into focus in clear detail the system's strong and weak points. These tests and study provide the basis for designing logical and economically efficient reinforcements by stages, as required presently and for the coming fifteen years.

With few exceptions the Salem water-distribution system was found adequate to deliver peak hour of peak day water demands without dropping water pressures below 30 pounds per square inch. The fire-flow tests showed that the capacity of the transmission mains from Folly Hill reservoir was more than ample to bring the maximum fire requirements plus the maximum hour demand for water, and this condition existed in spite of the low "C" factors prevalent throughout the system.

It was evident that, before basic improvements could be effected, a thorough systematic flushing of the distribution piping and the acquisition of a substantial amount of water storage inside the distribution system proper were needed.

The matter of flushing the system has been undertaken as a substitute for the Water Waste Survey and carried out in a

systematic manner. The purpose of the systematic flushing program was to clean the mains in the areas with the most dirty-water complaints; and to operate a large percentage of gates and hydrants to find out their operative condition. The method of systematic flushing was to start at a feeder main and isolate a stretch of pipe in such a manner that the flow was concentrated into this main. One or more hydrants, depending on the amount of flow, were opened in order to increase the velocity of the flow in the main, and thus remove the loose sediment from the inside walls of the pipe. The 4½-inch outlets on the Post hydrants were used at all times.

When there was more than one feeder main into an area, an assumption was made as to the approximate location of the balance point. This balance point is the place where the velocity of flow is equal to zero, because the water is fed from each feeder in equal amounts, therefore causing a static condition. All flushing of mains should start from the feeder main and work towards this balance point. The approximate amount of flow in the various mains was estimated by use of the rule of thumb that the flow varies in proportion to the diameter squared. Thus a 12-inch main is assumed to carry about four times as much water as a 6-inch main.

During the flushing program a large percentage of the Pratt & Cady type hydrants were noted to jump when opening and closing. These loose foot valves create water hammer when the hydrants are opened and could cause breakage in the mains and services. Most hydrants were excessively stiff in opening and closing because of lack of periodic greasing.

A study should be made of the necessary repair parts needed to rehabilitate all these hydrants, and such a program should be instituted. The valves were found to be equally poor in operating conditon. The valves are old and have stuffing-box leaks, worn brass seats, and bent stems. Many valves were found to be covered with dirt, and some have been buried.

As a result of the flushing program, more than 50 miles of pipe have been flushed. This amounts to 66% of the city's total mileage of pipe, excluding the main feeders outside the city limits.

The question of water storage resolved itself into choosing a site reasonably close to the center of demand, where elevation

and nature of the ground permit relatively low construction costs, and a unit of sufficient capacity to provide at least one full day of service even during normal summer-demand conditions. The major item in the plan for improving the Salem water system consists of the construction of a standpipe on Gallows Hill, capacity 5.3 million gallons, size about 100 feet in diameter and 90 feet high, plus the mains required adequately to connect it to the general feeder system.

Simultaneously with the construction of the new tank and its feeder connections, a reinforcing main should be laid in Grove Street, and check valves should be installed on the 30-inch and 36-inch supply mains where they enter the city, and also on the 30-inch force main in Conant Street, Beverly, north of the Folly Hill Reservoir inlet.

The new standpipe, connecting mains, and check valves will:

1. provide enough storage so that the city will be assured three days' normal service in emergencies which might occur due to pump or treatment-plant shutdown, or a serious break on the 30-inch line between the pumping station and the city;

2. permit abandoning the 20-inch transmission main through Beverly, the useful life of which has now been reached;

3. provide full floating reserve storage inside the distribution system itself, maintaining pressures at high points even during maximum draft conditions, plus a substantial margin of independence in the event of failure of source, Folly Hill reservoir, or the transmission lines;

4. reinforce the system sufficiently so that further developments can be carried out without jeopardizing the service;

5. prevent unnecessary loss of water from standpipe or reservoir in the event of serious breaks of the transmission lines.

The secondary item of improvements comprises essentially the cleaning and cement lining of several of the important feeders in the system so as to:

1. obtain full benefit from the proposed storage and connecting mains;

2. eliminate tuberculation and silt deposits in long stretches of main, the large diameters of which make it difficult to flush them effectively;

3. physically reinforce one stretch of vital transmission main so as to minimize the danger of future breaks;

4. reduce required pumping head with consequent power savings.

In order to permit the proposed cleaning and cement-lining work to be started and completed as one continuous operation, and also to reinforce the rather weak South Salem distribution grid, several stretches of new 12-inch main must first be installed.

Cleaning and cement lining should be done in the order prescribed in the report. When the cleaning and cement lining have been completed, Folly Hill reservoir may be temporarily put out of service and cleaned, and new impellers ordered for the two service pumps in the pumping station. These new impellers should be designed for a working head of 180 feet, the discharge to be governed by that head and the characteristics of the existing cases and electric motors. The new impellers will materially reduce the cost of the power required for pumping.

Additional mains are needed to remedy deficiencies in fire protection or to strengthen the system generally. They consist of several cross connections and a few dead-end tie-ins.

The estimated cost of all these improvements is about $800,000.

Due to constantly increased individual use, water supplies must always be increased, and as has just been shown, the passing of time tends to reduce existing supplies. Money must be spent, from time to time, to overcome these two shortage-causing factors. If this is done only under emergency conditions, much less will be obtained for the dollar spent than if it is done by carefully planned improvements.

THE CONTROL OF TASTES AND ODORS AT THE BILLERICA WATER TREATMENT PLANT

BY BARBARA E. HAWKES*

[Read at Chemists' Session, Jan. 21, 1960.]

The water supply for the town of Billerica, Massachusetts, is the Concord River and three gravel-packed wells which are situated on the bank of the river. The well water is corrosive with a pH of about 6.5 and an alkalinity of 30.0 ppm. It has an average concentration of 2.00 ppm for iron and 1.00 ppm for manganese. The hardness is 70.0; color 30.0; chloride 60.0; and free ammonia about 0.610 ppm, with total solids usually 200.0 ppm or greater. The carbon dioxide concentration varies, but has been as high as 70.0 ppm with an average of 40.0 ppm. Because of the high carbon dioxide content of the wells, relatively large amounts of alkali must be used in conjunction with alum, in order to neutralize the acidity. The manganese proves difficult to remove, and the draw-down rate is such that well water cannot be used exclusively at the customary 1.5-mgd rate of the treatment plant. River water is used almost entirely, with well water treated only occasionally when conditions require its use.

The quality of the raw Concord River water varies from season to season and from year to year. The condition of the water is subject to abrupt and sensational contrasts and striking incongruities. The water is aggressively corrosive with a pH of about 6.5. Alkalinities vary between 6.0 ppm (occurring in winter months) and 30.0 ppm (usually in summer) and have reached values as high as 40.0 ppm. The concentration of iron and manganese is about 0.20 and 0.05 ppm respectively in winter months and about 1.50 and 0.25 in dry summer weather, when the river water contains a relatively large proportion of ground water. The hardness ranges from 20.0 to 40.0 ppm. The free ammonia content varies widely and suddenly; values have been as low as 0.037 ppm and as high as 2.10 ppm. The free carbon

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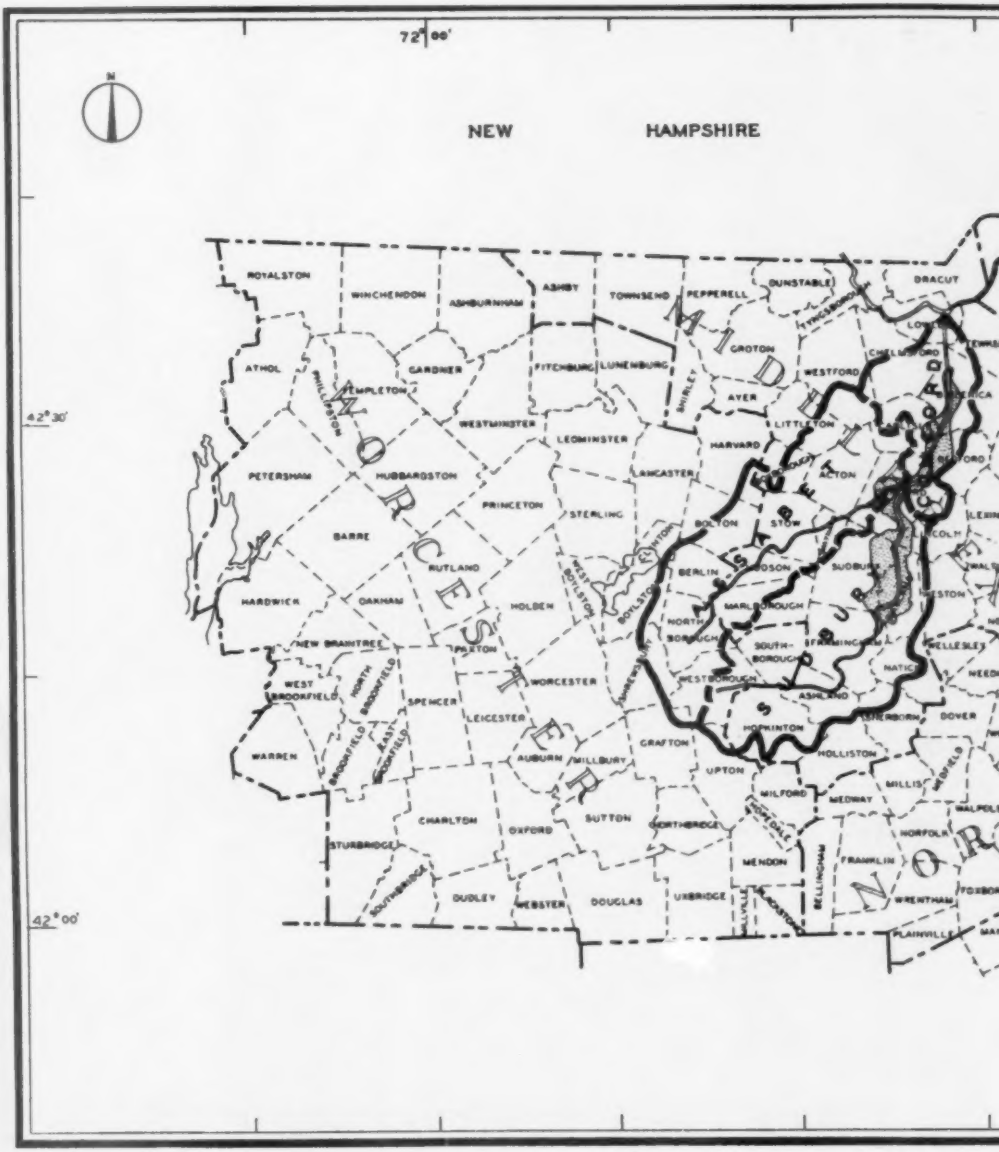
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GROTON
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WESTMINSTER
LEOMINSTER
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ACTON
PETERSHAM
HUBBARDSTON
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OAKHAM
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BOYLSTON
MARLBOROUGH
NORTH BOROUGH
SOUTH-BOROUGH
NEW BRAINTREE
PAXTON
WORCESTER
WEST BROOKFIELD
NORTH BROOKFIELD
EAST BROOKFIELD
SPENCER
LEICESTER
WESTBOROUGH
ASHLAND
HOPKINTON
DOVER
WARREN
AUBURN
MILLBURY
GRAFTON
HOLLISTON
UPTON
MILFORD
MEDWAY
CHARLTON
OXFORD
SUTTON
NORTHBRIDGE
STURBRIDGE
SOUTHBRIDGE
MENDON
FRANKLIN
DUDLEY
WEBSTER
DOUGLAS
UXBRIDGE
BELLINGHAM
WRENTHAM
PLAINVILLE
MIDDLESEX
NORFOLK

FIG. 1

THE COMMONWEALTH OF MASSACHUSETTS
SUDBURY VALLEY COMMISSION
CHAPTER 34, RESOLVES OF 1949

WATERSHEDS OF THE CONCORD, ASSABET AND SUDBURY RIVERS

CHAIRMAN OF STATE PLANNING BOARD
COMMISSIONER OF AGRICULTURE
COMMISSIONER OF CONSERVATION
COMMISSIONER OF PUBLIC HEALTH

ARTHUR C. COMEY, CONSULTING PLANNER

4 0 8 16
SCALE IN MILES

LEGEND

"VALLEY FLOOR"

MAP 1

dioxide is usually about 10.0 ppm, with total solids between 70.0 and 100.0 ppm. The raw river water has at all times a marshy or boggy odor, and with the advent of increased biological activity and the lower level of the river in the dry summer months, these odors usually become quite intense.

The etiology of the ever-present marshy odor can best be understood by a brief consideration of the watershed area (see Fig. 1). The Sudbury and Assabet Rivers unite in Concord to form the Concord River, which flows in a northerly direction into the Merrimack River in Lowell. The watershed, which includes extensive meadows and swamps with adjacent lowlands and gentle facing slopes, is 27.6 miles by river. An outstanding characteristic of the River from Saxonville to North Billerica is its almost level profile. There is only about a two-foot drop in low-water level between Stone Bridge, Wayland, and the North Billerica dam (a distance of 25 miles). The combined watersheds of the Sudbury, Assabet and Concord Rivers contain 402 square miles. The "valley floor" or central area is relatively flat and occupies 33 square miles. It lies between the Saxonville dam on the Sudbury and the North Billerica dam on the Concord, and includes the lower Assabet River as far as the dam in West Concord (Fig. 1). In the valley floor the river surface at normal low water contains 715 acres, and there are 3,012 acres of open grassy meadows, 2,155 acres of wooded swamps and 2,790 acres of flood plain (land below elevation 120 feet). The slopes of the valley floor occupy 12,680 acres. The meadows are chiefly unused grasslands and consist of peat and decomposed organic material. The trees in the wooded swamps are mostly red maple. A few houses occupy the flood plain, and the slopes facing the river contain farms, woodlands, decentralized residences and estates.

Pollution of the Assabet has increased steadily over the years and has produced similar pollution in the Concord River. Between Concord, where the Sudbury and Assabet join to form the Concord River, and North Billerica the river flows through low marshy meadows through a distance of 11.1 miles. In the spring flood seasons (and sometimes in summer and fall as well) the meadows are flooded. The large amount of water stored in these meadows and grassy lowlands recedes very slowly, gen-

erally taking two weeks to a month before the water drains off. The river bed contains a copious growth of various weeds. Duckweed (Lemna), which thrives in the presence of nitrogen and phosphorus, completely covers the river during certain seasons. This plant dies in the hot, late summer sun and in decomposing liberates its essential oils, thus creating an additional odor nuisance. The streams are sluggish in the summer and the rate of reproduction of the various plants exceeds the capacity of the rivers to drain them away (1).

The treatment plant, designed by Camp, Dresser and McKee, was placed in operation in January, 1956. The design of the plant is such that the operating personnel is able to produce an effluent of such constancy and good quality that the consumer is happily unaware of the difficult problems which the Concord River brings to them.

Chemicals utilized in the treatment of the water supply are alum, activated carbon, chlorine and sodium hydroxide. Chlorine dosages at all times exceed the breakpoint. Sodium hydroxide is used in conjunction with alum for flocculation when needed, and also for upward pH adjustment of the plant effluent to a noncorrosive range.

The intake station at the Billerica Water Treatment Plant is located on the banks of the Concord River and contains raw water pumps which transmit raw river water, well water, or a mixture of the two, to the pretreatment building. In the pretreatment building the water is first aerated and then proceeds to the contact chamber. After detention in the contact chamber, the water enters a pair of three-compartment flocculation chambers, followed by a pair of two-story sedimentation basins, and then flows by gravity to the filters. Following filtration the water is stored in the clear-well (see Fig. 2).

The plant design has incorporated features which permit the flexibility and afford the opportunity for the wide variation of treatment processes so necessary in dealing with the contingencies encountered in the river water. For prechlorination, chlorine can be added in the contact chamber, or it can be added along with alum and sodium hydroxide as the water enters the flocculation chambers. Postchlorination dosages can be added to the filter effluent header as the water enters the clear-well.

Activated carbon can be added to the inlet pipe of the contact chamber; or it may be applied along with alum and sodium hydroxide as the water enters the flocculation chambers; or it may be added to the filter influent.

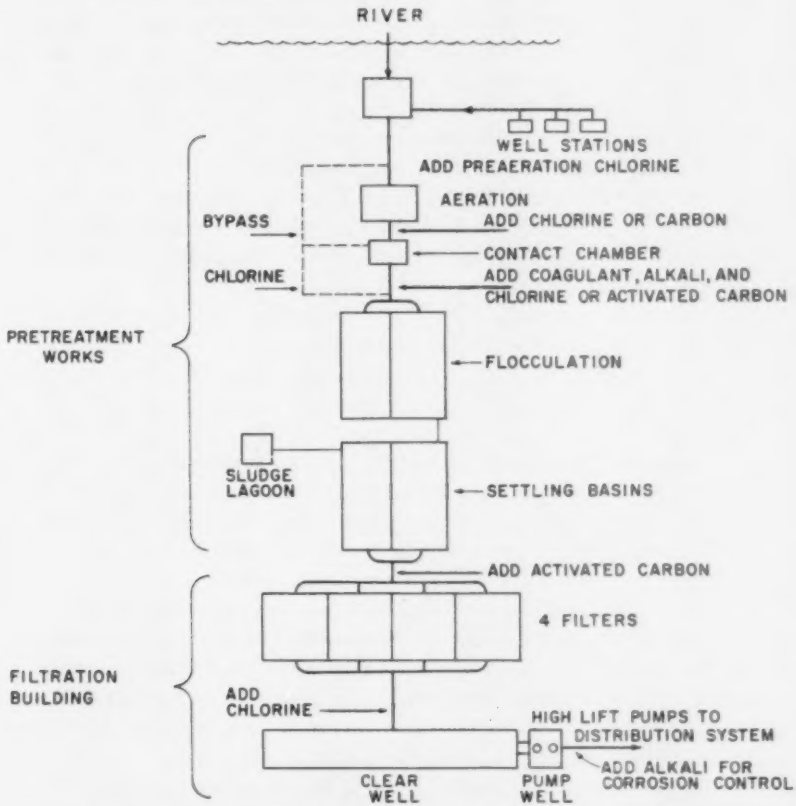


FIG. 2—FLOW DIAGRAM OF THE BILLERICA WATER TREATMENT PLANT

Under "normal" conditions, an application of about 6.0 ppm of activated carbon in the contact chamber (approximately 30 minutes' contact time at 1.5 mgd) is sufficient to remove the marshy odor. Following carbon contact, chlorine (in dosages one or two ppm in excess of the breakpoint), alum and alkali

are applied together at the entrance to the coagulation basin. For at least two or three months out of each year (usually between July and October) the swampy odor in the raw Concord River becomes of such intensity that high carbon dosages (varying from 20 to 100 ppm) are required for successful odor removal. In 1959 the period of intense odor began in mid-March, continued throughout the summer and on into October. Because carbon adsorbs chlorine on its surface, chlorine dosages must exceed the breakpoint by an average of 5.0 or 6.0 ppm instead of the usual 1.0 or 2.0 ppm just to maintain the practice of breakpoint chlorination, when carbon dosages are at such high levels (see Figures 3 and 4). Were it not for the dechlorinating effect of the activated carbon, chlorine dosages which exceed the breakpoint by as much as 5.0 or 6.0 ppm might be considered to be well within the range of superchlorination.

If superchlorination is to be effective as a means of odor removal, the chlorine present in the water must be in the form of free available chlorine. The oxidation potential of the chloramines is so low relative to that of hypochlorous acid that even high concentrations of combined available chlorine will not convert odorous compounds into non-odorous oxidation products. It is, therefore, a cardinal requirement, if the object is to destroy odorous compounds by the use of chlorine, that the breakpoint (no matter where it may lie on a scale of progressively higher dosages) be considered zero-chlorine application.

Superchlorination has been found to be successful for odor removal, although its usage has been rather limited. Super- and-dechlorination has been attempted in 12.0% of United States water treatment plants faced with odor problems due to decaying vegetation. Of these 30.0% have reported total success; 25.0% report partial success; and 45.0% report no success (2).

After extensive laboratory tests evaluating odor removal by activated carbon and superchlorination for the raw Concord River water, superchlorination was initiated at the Billerica Water Treatment Plant on June 11, 1959, in the following manner:

1. Chlorine was applied in the contact chamber in superchlorination dosages. Alum and alkali were applied as usual at the entrance to the coagulation basin.
2. Carbon was applied to the influent to the filters in dos-

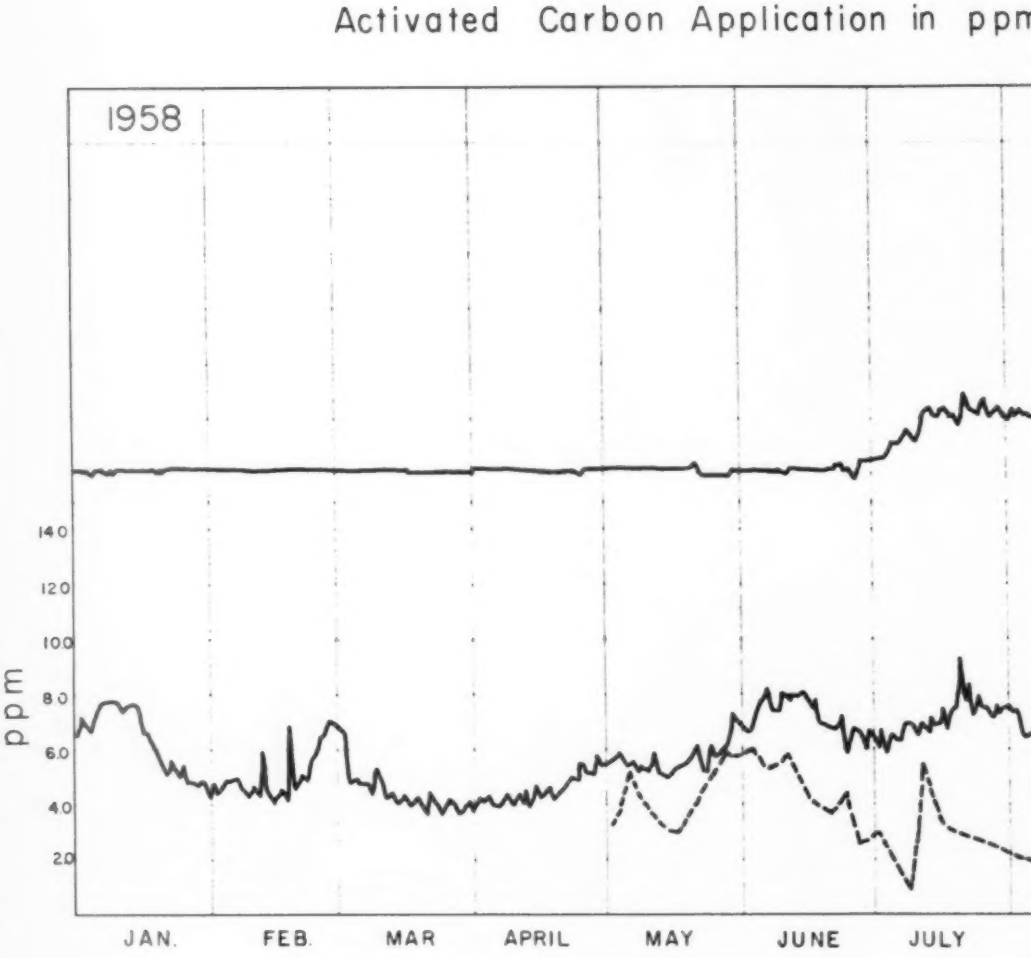
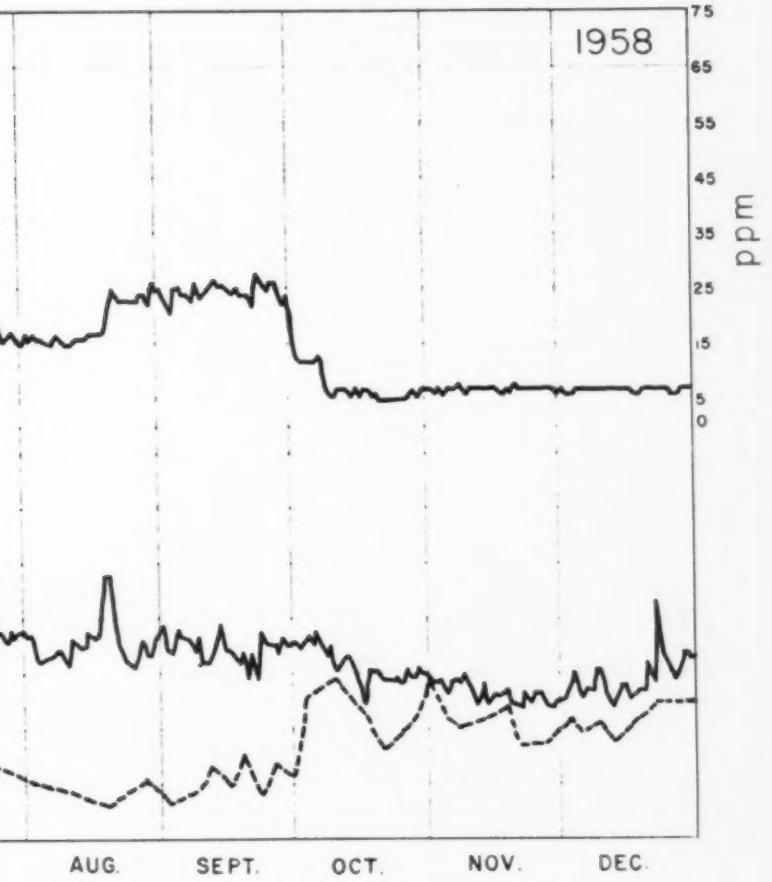

Activated Carbon Application in ppm
1958
140
120
100
80
60
40
20
ppm
JAN.
FEB.
MAR
APRIL
MAY
JUNE
JULY
Breakpoint, Concord River in
VS.
Pretreatment Application of Chlorin

FIG. 4.

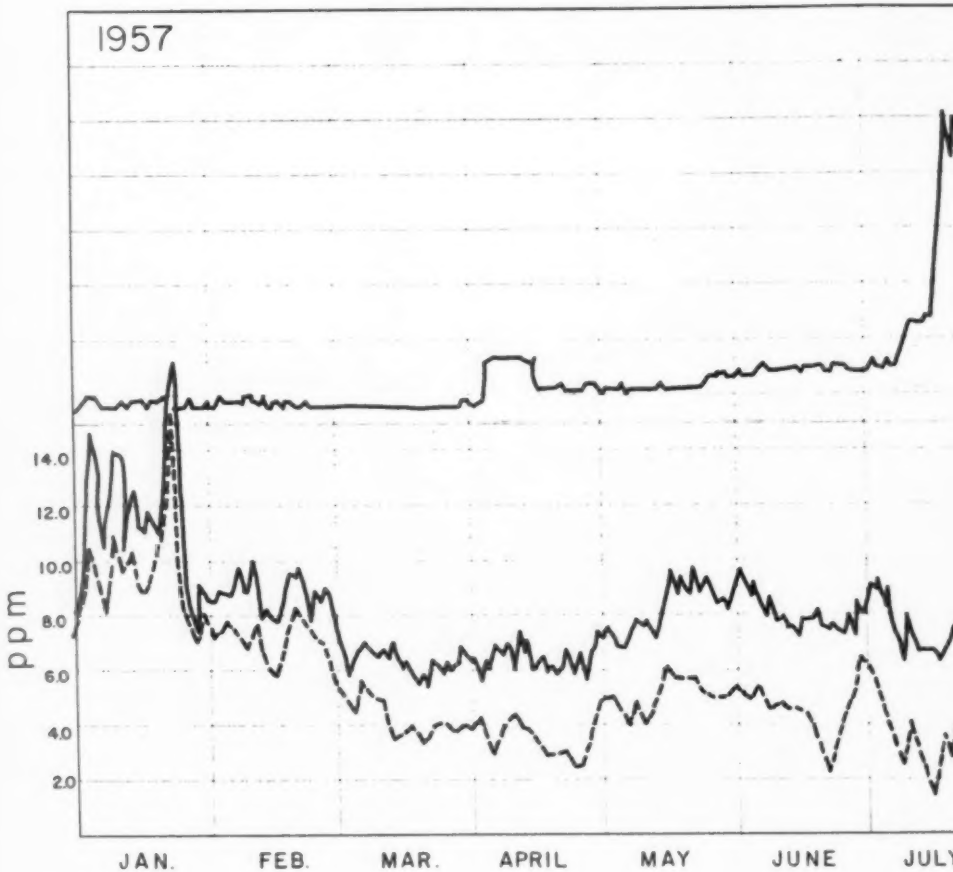
pm (Contact chamber)



in ppm (jar test) ------

orine to Raw Water —

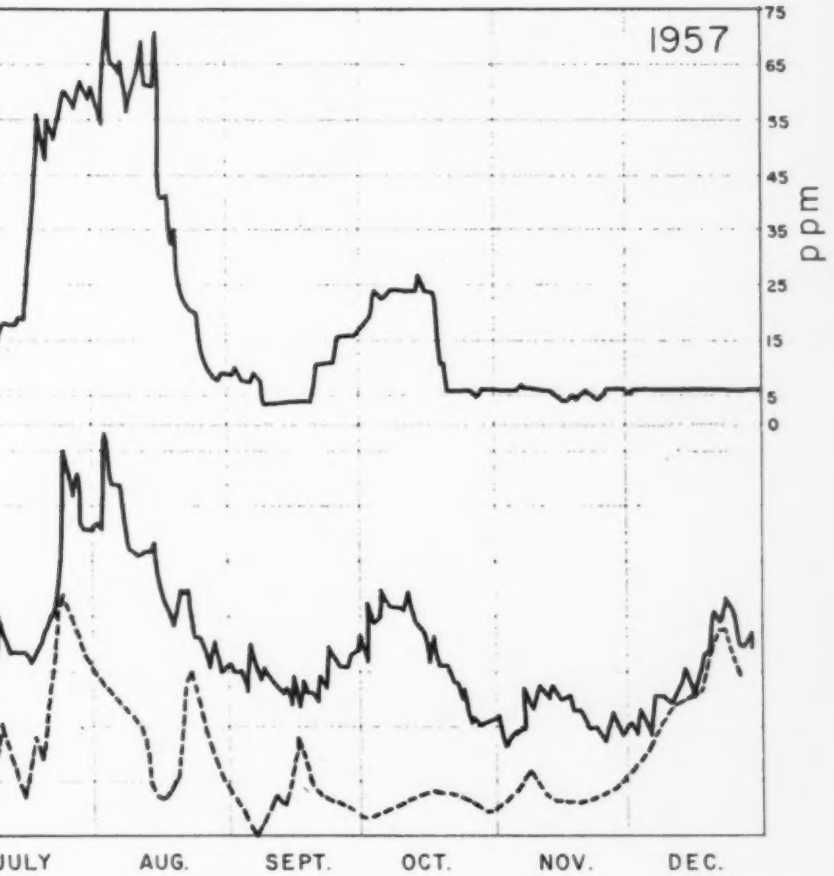
Activated Carbon Application in



Breakpoint, Concord River
vs
Pretreatment Application of Ch

FIG. 3.

in ppm (Contact chamber)



ver in ppm (jar test)------

Chlorine to Raw Water——

ages of approximately 5.0 ppm. Its usage here in such small amounts was for dechlorinating purposes. In accordance with values predetermined on a laboratory scale, free available chlorine residuals of from 4.0 to 6.0 ppm were obtained in the third coagulation basin (1½ hours' contact time). The free available was 95 to 100% of the total residual. The water entering the filters after a contact period of 4½ hours carried a free available residual of about 3.0 ppm. The dechlorinated filter effluent had a residual of 0.30 ppm free available chlorine.

This method produced a plant effluent in which there was a very faint boggy odor, detectable only to the experienced observer. Carbon dosages were reduced by approximately 250 pounds per day ($27.00 less each day). Chlorine usage was increased by about 50 to 75 pounds per day ($4.00 to $6.00 more per day). This represents a net saving of about $24.00 per day (see Table 1).

TABLE 1—COMPARISON OF COSTS

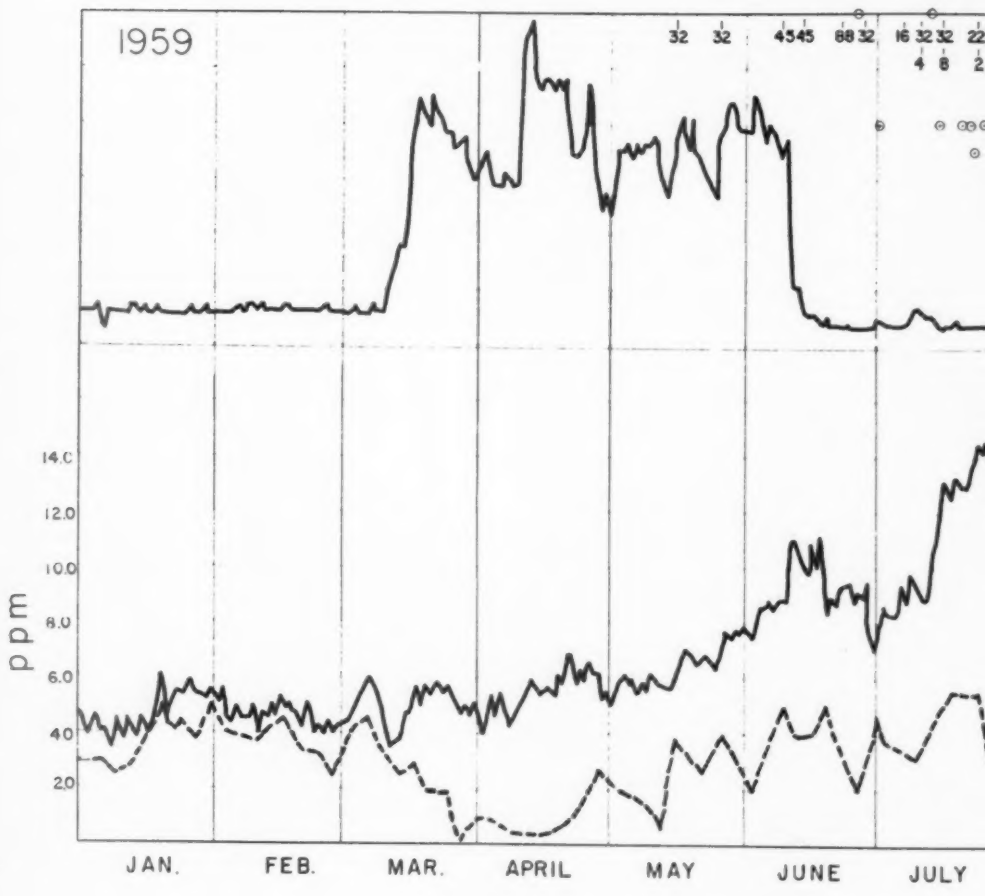
	Superchlorination	Activated carbon
Number of days used	96	94
Averages		
Water filtered per day	988,221 gallons	970,518 gallons
Carbon:		
Pounds used per day	44	304
Cost per day	$ 4.79	$33.08
Cost per million gallons	$ 4.85	$34.10
Chlorine:		
Pounds used per day	126	76
Cost per day	$ 9.83	$ 5.93
Cost per million gallons	$ 9.94	$ 6.10
Carbon plus chlorine cost:		
Cost per day	$14.62	$39.01
Cost per million gallons	$14.80	$40.20
Net Saving	$24.39 per day $25.40 per million gallons	

Throughout the period in which superchlorination was being used, the usual laboratory tests for determining the required activated carbon dosages were continued as a control for the experiment and to afford some measure of comparison. These tests indicated a wide variation in dosages required, but no

dosage was below 30.0 ppm (see Fig. 5). The circles on Figure 5 indicate where these dosages lie. Indicated laboratory dosages quite frequently are higher than those actually needed on a plant scale, but it is rare indeed if the amounts required in the laboratory exceed plant needs by more than 10.0 ppm. It is quite safe, then, to assume that no *plant* dosage would have been below 20.0 ppm.

It is well established that activated carbon will remove even the most difficult odors efficiently. In the Billerica Water Treatment Plant odors have been removed successfully with dosages as low as 5.0 or 6.0 ppm. Intense odors have required dosages as high as 100.0 ppm to produce a palatable effluent. A protracted period of difficulties requiring large amounts of activated carbon, such as we experienced in 1959, of necessity becomes quite costly. Our trial of superchlorination was initiated not as a substitute for activated carbon, but as a means of producing comparable results at a lower cost.

Toward the end of July, conditions in the Concord River began to change quite suddenly. The organic load began to increase, and the chlorine demand rose to such an extent that it became impossible to maintain free available chlorine residuals of 4.0 to 6.0 ppm after 1½ hours of chlorine contact. Indeed it was becoming difficult to obtain residuals of only 1.0 ppm free available chlorine. Laboratory tests conducted on the 29th of July indicated that in order to remove the intense putrescent odor which had developed in the river, the superchlorination dosage would have to be at least 50.0 to 60.0 ppm. The C.O.D. (chemical oxygen demand) at this time was 480 ppm, indicating an extremely high concentration of reducing substances. Since the maximum capacity for chlorine application of the treatment plant at 1.5 mgd is 24 ppm, the practice of applying activated carbon in the contact chamber was resumed, and chlorine was added along with alum and sodium hydroxide at the entrance to the coagulation basins. Laboratory tests revealed a slight septic, "dead animal" odor in a carbon dosage of 80 ppm, even after coagulation and settling of the sample, but a dosage of 60 ppm seemed to give as good results as the 80 ppm. Since, in the plant, time is on our side, 60 ppm activated carbon proved to be sufficient to remove the odor. The color of the raw water was reach-


Activated Carbon Application in
1959
32 32 4545 6832 16 32 32 22
4 8 2
14.0
12.0
10.0
8.0
6.0
4.0
2.0
ppm
JAN.
FEB.
MAR.
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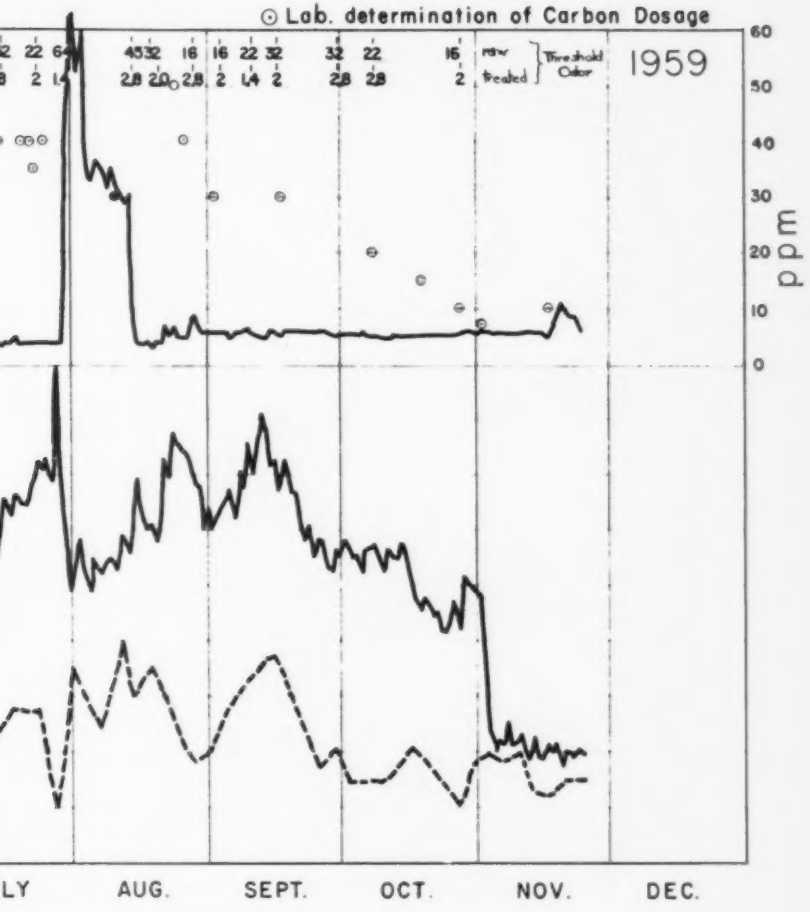
Breakpoint, Concord River
VS.
Pretreatment Application of Chlo

FIG. 5.

n ppm (Contact chamber)



er in ppm (jar test)------

Chlorine to Raw Water——

ing ever-increasing high levels at this time too. The color of natural waters is largely a function of the amount of organic material being carried in them (3). An approximate summer average for color varies between 70 and 90 ppm for the raw river water. The color reached 200 ppm during the last week in July. Alum dosages required to remove this color were in excess of 50 ppm (between 50 and 55 ppm), and even then color removal was not complete. The color of the plant effluent was about 15 ppm, and although Federal Standards allow a color of 20 ppm, a few (three) complaints about color were received. The consumers in Billerica have, since the start of operation of the new treatment plant, become accustomed to a color below 5.0 ppm, and the relatively sudden increase in color by 10.0 ppm may have been the reason for the complaints. It is highly probable, however, that the increased flow due to high water usage in the hot humid weather was removing deposits from the interior of the distribution system and contributing more color to the water.

Usage of the well water had been deferred on account of its high manganese concentration and because it was questionable whether the attenuant effect of the relatively non-odorous well water would be sufficient to show an appreciable reduction in activated carbon requirement. But along with the high color and intense odor in the river, iron and manganese values also soared to high levels (3.0 ppm for iron and 0.80 to 1.20 for manganese). Since the manganese concentration in the river could no longer be considered to be appreciably below that of the well water, the wells were placed in operation on July 30, 1959, and their yield represented 67.5% of the total water filtered. A carbon dosage of 35 ppm was found to be adequate to remove the odor from the combination of the river and well water. By greatly increasing the sodium hydroxide dosage, concurrently decreasing the alum, and applying 13 ppm chlorine it was possible to obtain a plant effluent with a color of 2.0 ppm and a combined iron and manganese concentration of 0.20 ppm (0.10 ppm each).

Fortunately, throughout this difficult period only two complaints were received concerning odor—and both of these on the last day before the abandoning of superchlorination, when we were not really superchlorinating. During the last three days of July, when the chlorine demand of the river made it impossible

to maintain "superchlorination residuals", the threshold odor of the plant effluent was 14.

By August 11th the color of the river had improved somewhat, and the usage of the well water was discontinued. By August 14th the chlorine demand had declined to more or less normal values, and the strong putrescent odor had disappeared, leaving only the intense boggy odor to contend with, and so the practice of superchlorination was reinstated (see Fig. 5).

Throughout the entire time that superchlorination was being used for odor removal, the threshold odor of the plant effluent varied between 2 and 8, and no complaints whatever were received. The median threshold odor of the raw water for the duration of the period in which superchlorination was used was 32. The median carbon dosage which would have been required was 40 ppm (determined by laboratory test).

Superchlorination proved to be a useful expedient for the town of Billerica in a year in which it appeared that the cost of odor removal alone would exceed the entire amount of money allotted for all chemicals together.

The author wishes to express deep appreciation to Mr. William Kerivan, Chief Operator, for his excellent maintenance of the treatment plant equipment and for his enthusiasm and willing coöperation, both in the use of superchlorination and in the writing of this paper; to Mr. Lawrence Bevis, Operator, for his conscientiousness in the carrying-out of duties; and to Mr. Paul McNulty, Operator, for his fine care of the plant.

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DESCRIPTION OF INSTALLATION OF AUTOMATIC DIATOMACEOUS-EARTH FILTERS AT SARATOGA, CALIFORNIA

BY GEORGE A. PETTERSEN*

[*Read Jan. 21, 1960.*]

The purpose of this paper is to describe briefly an installation of an automatic diatomaceous-earth filter on a public water supply at Saratoga California. The installation is rated at 5 million gallons per day and was installed at a total cost of $150,000. In New England, I would place the cost closer to $200,000, due to more stringent housing requirements.

Diatomaceous earth is the fossilized remains, skeletons or frustules of diatoms. Diatoms are single-celled aquatic plants, which have the ability to extract silica from the water in which they live. With it they form their skeleton of diatomaceous silica.

Several million years ago, the ocean covered much of North America's west coast and diatoms flourished in that area. When the waters receded, vast deposits of the diatoms' skeletons remained and are the present source of the diatomaceous earth as we know it. For the most part, it is mined and processed in California.

Diatomaceous-earth powders have very light weight in relation to bulk ranging from 7 to 13 pounds per cubic foot. This compares with sand at about 100 pounds per cubic foot. Diatomite has a tremendous surface area, ranging from 10,000 to 100,000 square feet per pound. Because of their intricate shapes and high porosity, the diatomite particles form a "straw-pile" type of mat, which has from 85% to 90% voids. These properties result in an unusual ability to permit fluids to pass through a cake of diatomite and filter out of the fluid almost all of its turbidity. Industry has used this to advantage in many thousand installations for clarifying water, oils, beer, pharmaceuticals and other fluids.

There are about 40 installations in the United States using

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diatomaceous earth as a filtering medium on public water supply. Their success has varied from mediocre to excellent, depending upon the peculiarities of each installation. The sizes of their systems vary from very small to 5 million gallons per day. A proposal has been submitted on a 26-mgd installation. Water quality and the economics of each installation differ radically, and flat statements cannot be made concerning conditions which limit the use of diatomaceous-earth filtration. However, some generalizations can be made.

This is a mechanical filtration process. Therefore, it is often considered where turbidity is a problem. Diatomaceous-earth filters can reduce the turbidity from as high as 50 parts per million to the normal guarantee of less than 1 part per million on one pass through the filters.

The addition of aluminum sulphate and soda ash, to form aluminum hydroxide floc on the filter aid, has met with substantial success in the laboratories for the removal of color. The floc is a "fresh" floc rather than a heavy, thick floc. It is believed that it coats the diatoms without actually closing the pores. Experience in color removal is being accumulated, and more specific information will be available in the near future. The addition of activated carbon or the use of a specially treated earth has been successful in removing taste and odor. Diatomaceous-earth filtration will completely remove activated carbon as well as algae.

Saratoga, California, is located in the foothills of the Santa Cruz Mountains, in an area that was once the world's chief source of quicksilver. The Saratoga filter plant and storage facility are enclosed in a 40-foot by 40-foot pre-fabricated metal building, located on one-half acre of mountainous terrain. The filter plant is installed in an open system, taking water from an 8-foot diameter wet well, which receives water from a screened intake in the creek. It discharges at a constant pre-set flow rate into a 2-million gallon reservoir, located ½ mile down-hill from the filter plant. The plant is rated at 5 million gallons per day at 1.6 gallons per minute per square foot of filter area. The total filter area is 2240 square feet. The flow rate can be adjusted from ½ mgd to 7.5 mgd by means of adjustable-speed magnetic couplings on the pump drives. The variable-speed drive

permits the pump discharge to be compatible with the amount of water flowing in the creek, and maintains a constant flow rate during the filter run. No power is wasted in throttling through rate-of-flow valves.

The filter plant is a base load plant, taking all the water from the stream that is available. In the summer, when the stream runs low, higher-cost water is pumped from deep wells. In the winter, with ample water in the stream, the filter plant operates at maximum capacity. It is expected that only when the turbidity increases to 50 parts per million for sustained periods of a day or more, will the filtering cost exceed the cost of pumping water from the deep wells. Their deep wells are 250 feet deep. The power cost for pumping from the deep wells is approximately 3.5 cents per 1000 gallons.

The filter septum is a monel wire-screen tube, mounted vertically in the filter tank. The inlet water enters the bottom of the tank and passes from the outside of the tube to the center of the tube and then to the filtered-water area at the top of the tank. The diatomaceous earth bridges the screen openings and forms a cake around the tube.

The operation is essentially as follows: Each filter run begins with the pre-coating of the wire-mesh filtering tubes. The pre-coat is about 1/16″ thick. When the precoating is completed, the filter is switched onto the line automatically. Diatomaceous earth is fed continuously into the incoming water, which carries it to the tube. The diatomaceous earth forms a porous cake on top of the pre-coat. As the cake gradually builds up, the pressure between the input and outflow of the filter tank increases to a pre-determined maximum differential, approximately 30 psi. The filter then automatically ends the run, back-washes itself, repeats the pre-coating operation and goes back into service. The cleaning and pre-coating operation is accomplished in only 15 minutes and utilizes about one-tenth of one per cent of filtered water for the backwashing and rinsing operation. A filter run—that is, the time it takes to form the cake—will vary with the amount and nature of turbidity present. A period of three to four days is normal for turbidities to 3 ppm (24 to 36 hours could be expected for a turbidity of 10 pp), on water such as that at the Saratoga plant.

The only manual labor required is the refilling of the diatomaceous earth slurry tank. In some plants this is done by the assigned pump man, once a day, and he also replenishes the chlorine supply and takes records. This operation takes less than an hour each day.

The filter plant at Saratoga consists of two De Laval duplex filters, operating in parallel. Each duplex unit is capable of handling 1800 gpm at the filter rate of 1.6 gpsfm. Each consists of two 60″-diameter filter tanks, a 60-hp K 10/8 horizontal pump, motor-driven through an adjustable-speed magnetic coupling, a small body-feed (filter aid) pump, a small air compressor and a control panel. One slurry tank serves all four of the filter tanks and contains a mixer which keeps the slurry continuously agitated. The slurry concentration is 20% of diatomaceous earth.

One feature of the control panel is the body-feed regulating dial. This permits the rate of body feed being injected into the raw-water stream to be changed by merely turning the dial. Should there be a period of high turbidity, due to flashing of the stream, more body feed can be added by turning the dial and the temporary problem can be handled easily.

The used diatomaceous earth is flushed during the backwash and rinsing operation through an outlet at the bottom of the tank into a trench (covered over) and thence out into a sludge pit in the yard adjacent to the filter building. The sludge pit is approximately 50 feet long, 15 feet wide and 5 feet deep. Settled water overflows to a drainage area. The sludge is removed by truck at intervals during the year.

The major feature of this installation, and the basic reason municipal application is feasible, is the automatic controls incorporated into it.

The control is such that:

1. The automatic control shall cause the filter to go through a cleaning cycle at a pre-set pressure differential across the cake and then go back on the line.
2. The filter unit shall not deliver water to service without first being properly pre-coated.
3. A power interruption shall cause the effluent valves to close and the filters to drain.

4. A resumption of power shall cause the filters to go through a complete cleaning cycle and then go back on the line.

5. In the event that there is inadequate flow to the filter pumps, the effluent valve will close, the filter will recirculate to hold the cake, and the effluent valve will open upon restoration of the proper level in the wet wall.

This installation was completed in November, 1959; the shake-down and adjustment period was the month of December, and it went on stream in January, 1960. The assurance with which it was built and placed in operation was based on a similar, although smaller, unit which has been operating on the same water nearby for two and one-half years. It is located at the small mining community of New Almaden, California, and is rated at 190 gpm with maximum capacity of 250 gpm. It has been delivering clear water to Almaden without interruption, handling turbidities ranging from 2 parts per million to 1300 parts per million successfully and automatically.

At 3ppm, total operating costs—diatomite, power and labor costs—have run a little more than ½ cent per 1000 gallons. At 10 ppm, costs are about 1 cent per 1000 gallons.

Another 2½-mgd installation is on order for the town of Hemet, California, but is not yet in service.

These filter installations on public water supplies make for optimism that other communities in the United States will solve their filtering problems with automatic diatomaceous-earth filters.

THE DETECTION OF TRACES OF MATERIALS IN WATER WITH SPOT TESTS

BY ERNEST A. SNOW*

[*Read at Chemists' Session, Feb. 18, 1960.*]

The detection of small amounts of foreign materials in water is certainly not anything new. It has been going on for years. However, the increased use of chemicals for treatment of drinking waters and the addition of others for corrosion control has increased the possibilities of unwanted materials entering our drinking water.

The use of spot tests came into general use in the 1930's due to two special circumstances and popularization by Feigl et al. First, the use of organic reagents tended to make the tests more sensitive and specific. Second, the use of these tests is generally saving of both time and material. This is especially important when only small amounts of material such as corrosion products are available for the tests. This economy of time and material fitted in with the psychology of the "depression" era and spot tests have become an accepted part of qualitative analysis.

Before we proceed further it might be well if we explained what spot tests are in case someone here does not know. A spot test is one in which a chemical reaction is obtained within the volume of a few drops of reagent and unknown solution. Either a specific color or precipitate is the result and this is indicative of a specific anion or cation. Further, the test should not require the aid of any optical instrument to determine the outcome.

No reaction is suitable for these tests if the limit of identification exceeds 10 y (gamma) $\begin{cases} 1\text{y} = .001 \text{ mg.} \\ 10\text{ y} = .01 \text{ mg.} \end{cases}$. The most important factor in micro-chemical tests is the ability to detect minimal quantities. Although very small weights of material can be tested, when converted to numbers of molecules the figures are very large, e.g. if .005 gamma of NH_3 in one drop is detected there are approximately 170 million million molecules present.

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Strictly speaking, we seldom achieve absolute certainty of tests but only a certainty within particular limits of the concentration of accompanying materials. For this reason it is generally better to separate the cations, e.g. into groups as in ordinary qualitative analysis and then test for individual cations within the group.

There are six different types of reactions with organic reagents:

1. Those producing normal salts with inorganic ions due to their acid or basic character, ex. oxalates, aniline with some metals.
2. Acid reagents giving inner complex salts by coordination of auxiliary valences, ex. dipicrylamine, dimethyl glyoxime, rubeanic acid.
3. Addition compounds formed by whole molecules with inorganic ions or molecules, ex. aniline and cation.
4. Adsorption complexes, ex. brilliant yel. with Mg.
5. Reagents that change color on oxidation or reduction, ex. benzidine with Mn.
6. Reagents that react in a characteristic manner after inorganic groups have been incorporated in them, ex. zinc thiocarbamate with Cu.

One method of spot testing is to carry on the reactions on porcelain spot plates. These plates are available in several sizes generally having from 3 to 12 depressions in them. The depressions hold several drops and the white color of the porcelain is good contrast for the colors or colored ppts produced.

In case light colors or white ppts only are formed, there are black spot-test plates available. But in this case it is easier to use small watch glasses or vials to carry out the test and use black paper for the background. Although ordinary filter paper can be used for spot tests there are available several special spot-test papers. They may be obtained in the usual circles or in large rectangles. It is often conveneint to cut the rectangles into small strips for testing.

A number of tests require that the reagent be applied to paper and dried before use. This is convenently done with strips cut from the large rectangles. Another technique is to have spot-test papers with circles of definite size made with a water-insoluble material such as paraffin or plastic. These are called confined

spot-test papers and can be used for semi-quantitative results using increasing quantities of a standard for comparison.

Another adjunct to spot testing is the use of fluorescent light to show up spots due to special reagents. For example:

Al by morin in U-V light	ident. limit = .005 μg
U by NaF melt in U-V light	ident. limit = .001 μg
Cd by oxine	
Li by oxine	ident. limit = 3 μg
Be by benzoin	ident. limit = 1 μg

A quartz lamp or other source of U-V light is needed to show up the fluorescence in a dark room. Of course most of the tests can be made strictly quantitative if a fluorometer is used. Other techniques are also used such as micro distillation, sublimation and ion exchange for certain tests. (See also electrographic test for copper, page 255.

Individual tests for cations and anions found in treated waters or corrosion products:

Aluminum: Spot tests with alizarin and aluminon.

Fluorescent tests with pontachrome BBR, morin or oxine.

Ammonia: Nessler reagent will give a spot test.

Calcium: 1. Ammonium ferrocyanide and alcohol give a white ppt.

2. Sodium dihydroxytartrate osazone gives a ppt with 0.2 ppm.

Copper: There are many reagents for copper. Among the best are: rubeanic acid in alcohol, a benzoin oxime, salicyl-aldoxime.

Iron: There are also many reagents for this element. Since it is important in corrosion studies to know the valence of the iron, tests for both ferrous and ferric ions should be carried out.

Ferrous iron: alpha alpha dipyridyl—red color.

Potassium ferricyanide: green-blue ppt.

Ferric iron: ferrocyanide—blue ppt.

Oxine: dark green.

Sulfosalicylic acid: wine color.

Lead:

Since lead is a cumulative poison its presence in drinking water is potentially dangerous to the consumer.

1. Benzidine with 1 · 3 NH_3 and H_2O_2 ---→ blue color.
2. Sodium rhodizonate (0.1% alc.) on filter paper ---→ red ppt.
3. Dithizone in $CHC1_3$ or $CC1_4$ (pH 8–10) ---→ cherry red.

Magnesium:

The hydroxide with I-KI gives a brown adsorption complex.
Quinalizarin in alkaline solution gives blue ppt or color.
Thiazole in alkaline solution orange or red color.
Titan yellow and other dyes give red ppt.

A very good reagent for small amounts of Mg is made as follows: Dissolve .01 gm. brilliant yellow (C1364) in 50 ml D.W. + 50 ml CH_3OH. Mix 1 part of above with 9 parts clear saturated limewater. Add one drop of sample to 4 or 5 drops of reagent. Red color or ppt shows Mg. (Ref. Chemist Analyst, Mar., 1957, vol. 46, #1, p. 4).

Manganese:

To unknown add 2 drops saturated potassium periodate, 1 drop acetic acid (dil.) and then 3–4 drops of tetramethyl diaminodiphenyl methane in chloroform. A bright blue color shows Mn.

Another new reagent is silver peroxide. To make the test add dil H_2SO_4 + pinch of Ag_2O_2, stir(filter thru fritted glass crucible. Purple color in filtrate shows Mn.

Potassium:

This reaction is more sensitive on filter paper. Put drop of neutral unknown on filter paper. Add a drop of sod. dipicryl amine in sod. carbonate, then a drop of 1:5 HCl. An orange-red spot remains if K was present. Cs, Rb and NH_4 interfere. Gentle ignition of unknown first will get rid of the NH_4 ion.

Another new reagent for K is sod. tetraphenyl boron. Make a 3% solution of this in water, add 1 ml alumina paste, stir and filter. Buffer the unknown at pH 5.4, 1 drop, and add 1 drop EDTA solution and 1 drop reagent. A white ppt shows K (if NH_4 is absent also).

Buffer = 11.25 gm acetic acid and 110 gms sod. acetate in 500 ml D.W.

EDTA soln. = 37% EDTA.

Ref. Chemist Analyst, vol. 46, #1, p. 6. ident. limit = .09 μg.

Sodium:

There is no really good reagent for sodium yet. The best is zinc uranyl acetate which gives a yellow ppt, but the sensitivity is .01 mg in 250 ppm concentration. A more sensitive spot test would be welcomed.

Zinc:

This cation gives a white spot on molybdate ferricyanide paper (brown). This white spot will turn red on applying dithizone and NH_3 to it. Another drop test for zinc is the reaction with Orange IV (.01%) plus 1 drop dil. H_2SO_4 + 1 drop 2% potassium ferricyanide. Zinc gives a green color. If the Orange IV is replaced by diethyl aniline a red color or ppt is formed.

Anion Tests

Fluoride:

The zirconium alizarin reaction can be used as a spot test. This is best conducted on paper impregnated with the reagent and dried. Put a drop of 50% acetic acid on the paper and 1 drop unknown. A yellow spot on the red paper shows fluoride if oxalates, sulfates and phosphates are absent. Oxalate may be ignited away, sulfate may be precipitated with benzidine — HCl. Limit .001 mg F.

Nitrate:

3 mg brucine in 1 drop conc. H_2SO_4 gives a bright red color with 1 drop of nitrate solution, which fades to a yellow-red on standing. Limit is .00006 mg nitric acid in 1 ppm.

Phosphate:

1 drop of molybdate reagent plus a speck of stannaver powder gives a blue color with phospates on stirring. Molybdate reagent: 5% ammonium molybdate in 31% sulfuric acid.

Interferences: chromate, iron, tannin, As, V and polyphosphates.

Silicates:

In the absence of PO_4 the following test works very well. To one drop unknown add 1 drop molybdate reagent (see above) and a pinch of hydroquinone crystals. Stir, yellow color is developed, add excess KOH, and stir; color changes to green-blue and gas is evolved. The reagents above give a yellow-green with KOH alone.

Sulfates:

Barium rhodizonate (red ppt) is decolorized by sulfates in either acid or alkaline solution. This reaction may be done on spot plate or even better on filter paper.

Sulfides: The iodine-azide reaction is very sensitive, the reagent is decolorized and bubbles of N_2 given off in the presence of any $S^=$ linkage. Another test is the violet color produced with 1% sod. nitroprusside and 50% NH_4OH.

Sulfite: Mix 1 drop 10% $K_4Fe(CN)_6$, 1 drop cold sat'd zinc sulfate and 1 drop 1% sod nitroprusside. This gives a white ppt. Add 1 drop of unknown (neutral). A red color shows that sulfite is present.

Electrographic test for copper

An electrographic test is one especially suited for checking impurities in alloys. Clean the test area with soapy water, alcohol or acetone. Make the alloy the anode by connecting it to a 6-volt dry cell, use alligator clip. Connect negative terminal to a stainless steel electrode over a pad of 2–4 thicknesses of Whatman #50 filter paper moistened with K_2SO_4 (5% soln). The current flow thru pad causes metal ions to leave alloy and deposit in pad. Remove cathode after 30–60 seconds, spot paper with reagent.

A good test for copper is to add one drop of o-tolidine thiocyanate reagent to pad. A blue color shows copper. Iron gives a red brown color. The reagent is made by dissolving 0.1 gm. o-tolidine and 0.5 gm ammonium thiocyanate in 5 ml acetone. This should be made up fresh each day as needed.

As a cross-check, spot another pad with rubeanic acid. This gives an olive green to black color with copper.

A recent example of the utility of these tests is their use

in checking the corrosion of aluminum components in a nuclear reactor. Ref.: Nucleonics Data Sheet #7.

A few precautions in the use of spot tests might be relevant at this time.

1. The sensitivity of some of the reagents is so great that care should be taken in the interpretation of results, e.g. a trace of zinc might have little meaning in a corrosion test whereas large amounts could be important.

2. Many organic reagents are unstable to heat and light (esp. U-V). Some reagents will have to be made up just before making the test, e.g. see above test for Cu with o-tolidine thiocyanate. Dithizone is light sensitive so should be kept in amber bottles and preferably in an ice box.

3. If tests are made without previous group separations many interfering substances may be present to make interpretations difficult.

4. Spot tests should never take the place of quantitative analysis except when semi-quantitative results are suitable to give results desired.

5. It is often desirable to make parallel tests with known compounds, esp. if the test is new to the user.

To simplify the application of these spot tests, certain supply houses have made up kits containing all the uncommon reagents (in dry form) needed for the usual inorganic qualitative analyses. Special acid dropper bottles, spatulas, funnels and spot plates are also available.

For the separation of metal ions into groups, several schemes have been worked out. The classical scheme of Noyes including the use of hydrogen sulfide is still extensively used. Several methods to eliminate the vile odor of sulfide have been tried. One scheme was devised by C. B. Day of Canada and revised by the author to adapt it to spot tests. This method uses aniline and aniline thiocyanate instead of H_2S.

Another more recent reagent is using thioacetamide to replace the H_2S. This may have advantages but the solution will probably have to be evaporated and ignited between group separations.

Another method of partial separation is often useful when only a few metals are present. This e.g. involves the use of a

COMPARATIVE TABLE OF QUALITATIVE METHODS

Method	Use	Advantages	Drawbacks	Range	Comparative cost*
Ordinary	General anal.	Simple	Tedious	1-50 gms.	1
Odorimetry	Limited to odor cpds.	More sensitive than spectroscope	Methods and data needed	ppb or less $< 10^7$ molecules	2
Spot tests	General and special	Economical sensitive	Many reagents unstable	Micrograms 10^{14} molecules	3
Chemical microscopy	Molecular compounds	Systematic sensitive	Special techniques	mg-gm range	4
Polarography	Reducible compounds	Both qual. and quant.	Special techniques	0.1 ml of molal solution	5
Spectroscopy	Metals only	Both qual. and quant.	Special techniques	1-10 microgram	6
Optical crystallography	Crystals only	Rapid Sample unchanged	Special techniques	1-10 mg	7
X-ray spectra	Crystals and powders	Gives identity and structure	Special techniques	mg	8
Neutron activation	Gen. cations	Most sensitive method yet	Time and expensive apparatus	10^{-10} to 10^{-14} gms	9

*N.B. #1–4 in \$100—\$900 range
#5–9 in \$1000—\$9000 range
#10 above \$10,000

Note: The above table has been revised from the slide shown when this paper was given.

general reagent which precipitates different metals under acid and alkaline conditions or in definite pH ranges. An example is oxine or 8-OH quinoline. Mg and Be can be separated from many metals by adding acid reagent first, filter off unwanted metals and make alkaline with ammonia.

It might be of interest to compare some of the many methods of qualitative analysis as to cost, sensitivity, advantages, etc. See table.

Three additional methods should be mentioned:

1. fluorimetry: somewhat limited to a few metals.
2. chromatography: partial separations and generally uses spot tests for final identification.
3. neutron activation analysis: nuclear reactors are now used to make the sample radioactive; this is probably the most sensitive method of trace analysis today for most metals: varying from 1×10^{-10} to 9×10^{-13} gm.

This last method is from 10 to 100 times more sensitive than the spot-test reactions. However, the time and equipment needed are a drawback and expense.

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REMOVAL OF RESERVOIR DEBRIS WHILE MAINTAINING WATER SERVICE

BY PETER C. KARALEKAS* AND CHARLES A. MANGANARO**

[*Read Feb. 18, 1960.*]

The city of Springfield, Massachusetts, has recently completed a unique project by restoring an important reservoir link in the supply system while maintaining water service to a population of almost 200,000 persons.

The destructive hurricanes of August, 1955, discharged about 100,000 cubic yards of flood debris into the city's intake reservoir, reducing its capacity by more than 35 percent, and impairing its usefulness as a settling basin and storage reservoir upstream of the filter plant.

The problems of design and construction involved in clearing the reservoir of sediment and debris and installing bypass facilities will be described in this article.

Description of Facilities

Water for the city of Springfield is collected from the Little River watershed area of 45.5 square miles and is impounded in two reservoirs: Borden Brook Reservoir having a capacity of 2.5 billion gallons, and Cobble Mountain Reservoir having a capacity of 22.5 billion gallons. Water from Cobble Mountain Reservoir, the lower reservoir, normally flows through a 10-foot diameter tunnel to the hydroelectric plant owned by the city and leased to Western Massachusetts Electric Company. Flow may also be diverted to the paralleling Little River stream bed during floods or in the event that repairs are required to the tunnel. The power plant is immediately upstream of the intake reservoir. This may be seen in Figure 1.

A horseshoe-shaped tunnel conveys water from the intake reservoir dam to the raw-water settling basin of the West Parish Filter Plant, a distance of approximately 6,200 feet. This tunnel

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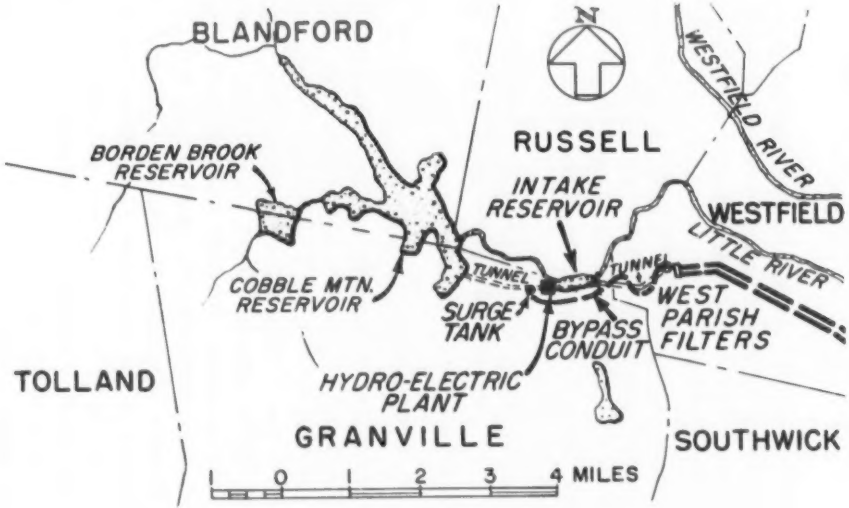


LOCALITY MAP

FIGURE 1

is a vital link in the water system, and until this year there have been no means for delivering water to the filtration plant in the event of damage to the tunnel.

Flood Flows "Connie" and "Diane"

Two hurricanes during August, 1955, in rapid succession, deluged the area with record rainfall and runoff. During this month, the total precipitation was 28.5 inches (compared to a monthly average of about 4 inches). Of this, 9.4 inches was dropped by hurricane "Connie" and, 3 days later, 17.4 inches by "Diane". The one-day peak reached 14.1 inches compared with the previous record of 6.2 inches in 1927.

Runoff from the second storm, the ground having been well saturated by "Connie", was 68 percent of the record rainfall, compared with the usual 55 percent. This resulted in highly destructive floods, washing downstream large quantities of soil material and debris.

The water level in Cobble Mountain Reservoir is usually kept down during periods when flood flows can be expected and, therefore, acts as a flood control reservoir to the benefit of the City of Westfield and industries located on Little River below the power plant. On August 11, 1955, prior to hurricane "Connie", the water elevation in the reservoir was 939 feet, providing an available storage capacity of 13 feet below the top of spillway at elevation 952, or 4½ billion gallons, which is equivalent to 5½ inches of 100 percent runoff. The combination of the two hurricanes caused the reservoir to rise to elevation 960, or 8 feet above the crest of the spillway, producing a disastrous discharge of 12,850 cubic feet per second. It was not until August 22, 1955, that Cobble Mountain Reservoir stopped overflowing.

As a result of these flows, the intake reservoir was filled with approximately 100,000 cubic yards of debris and sediment carried largely by flood waters, but augmented from nine land slides within its own precipitous catchment area. The power plant was submerged with land slides and its access road washed out in several places. Fortunately, there was no structural damage to cause failure of the water works system.

The Problems

The problem of removing sediment and debris from the intake reservoir while maintaining service to the city was complicated by the fact that the intake reservoir is located in a gorge within the Holyoke Mountain range, with steep access roads making the transportation of materials to be removed difficult.

The time-table for the removal also had to be dovetailed with Western Massachusetts Electric Company operations, since the hydroelectric plant operates on a peak load basis. Because of provisions of the 1932 agreement with the power company, the city would have lost substantial revenue if the hydroelectric plant were inoperative over a long period of time.

It was mutually agreed with the Western Massachusetts Electric Company that the removal operations in the intake reservoir must be completed within a 62-day period from July 1 to August 31, or high daily damage would be payable by the city.

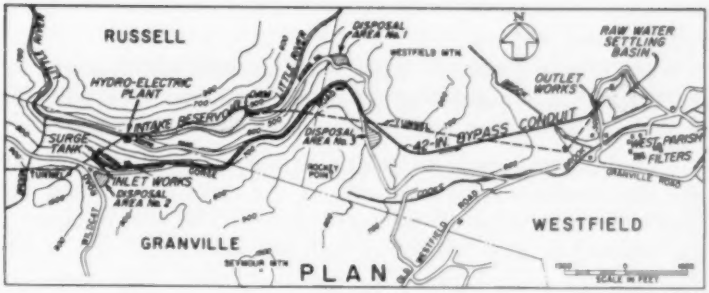
Consideration also had to be given to the water quality at the intake to the Stevens Paper Company, located about 4.0 miles downstream of the intake reservoir.

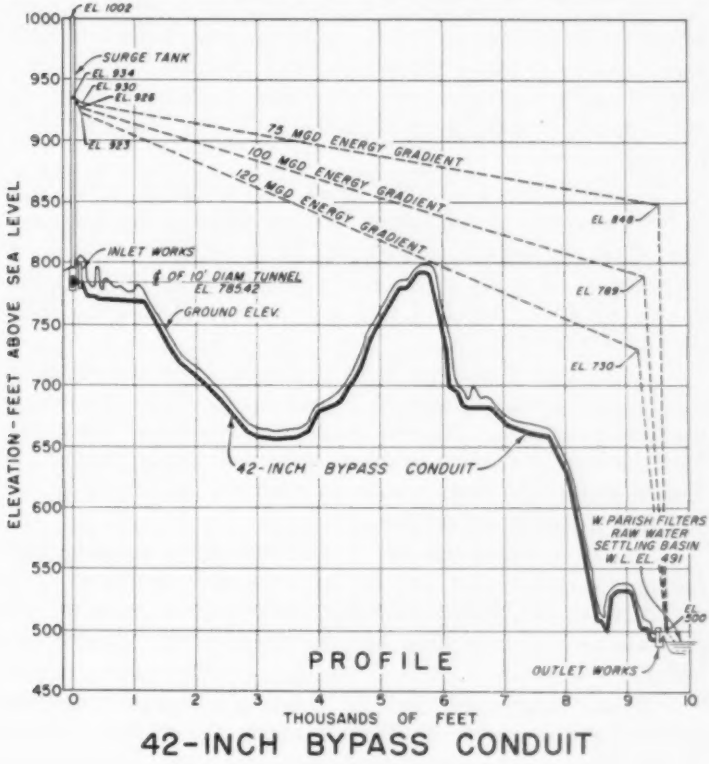
Perhaps most unique among the problems encountered was the need for energy dissipation in a proposed bypass conduit. As may be observed in Figure 2, the elevation drop alone (not including inlet pressures and water hammer), from the base of the surge tank at the hydroelectric plant to the raw-water basin at the filter plant, is almost 300 feet in a total distance of only 9,400 feet.

Design Criteria for Bypass Conduit

Preliminary studies and estimates indicated to the Board of Water Commissioners that there should be installed a permanent bypass (rather than a temporary bypass) to the raw-water settling basin at the West Parish Filter Plant for the following reasons:

1. It would provide a duplicate facility for the tunnel downstream of the intake reservoir and thus permit periodic inspections of the tunnel and enable the making of repairs.
2. It would reduce the cost and inconvenience of subsequent removal of materials from the intake reservoir.
3. It would provide a dependable water supply during the





42-INCH BYPASS CONDUIT

FIGURE 2

period that removal of debris and sediment from the intake reservoir was underway.

4. It would provide wash water at sufficient pressure for the West Parish Filter Plant, and thus eliminate the pumping of wash water to a high-level tank—an expense for 50 years.

Studies were made to determine the optimum diameter of pipe that would provide a capacity in the order of 100 mgd and keep velocities below 20 feet per second. The design capacity was selected to allow for future increases in demand beyond the present filter plant capacity of about 56 mgd. The maximum velocity of 20 feet per second was established to minimize scour or erosion of the conduit, while maintaining lost head to a maximum in order to lessen the energy to be dissipated at the outlet end. Based on these criteria, a 42-inch diameter conduit was selected, giving a maximum velocity for a 100 mgd flow of 16 feet per second.

It was assumed that the debris and sediment would have to be removed from the intake reservoir about every ten years. Therefore, the bypass conduit will be in future service on an intermittent basis for possibly two months every decade unless its use would be required during repairs to the tunnel below the intake reservoir.

It is expected that the levels in Cobble Mountain Reservoir will be held down as much as 25 feet during future cleaning of the intake reservoir. This will permit impounding of water from flash floods so that work in the reservoir will not be flooded out. The hydraulic gradients shown on Figure 2 are based on this assumed operational condition.

Studies indicated that the type of pipe which would be satisfactory for this service, and for the velocities mentioned above would be (a) concrete cylinder pipe either prestressed or not prestressed, or (b) steel pipe with a cement mortar coating and lining.

It was determined that the point of upstream connection for the bypass conduit would be made at the 10-foot diameter power-supply tunnel near the existing surge tank. This point of connection was selected since it provided for a completely buried conduit as opposed to a connection at the surge tank or the pen-

stocks of the hydroelectric plant where the conduit would be partially exposed and subject to possible damage.

The point of outlet for the conduit was set at the raw-water settling basin thereby completely bypassing the intake reservoir and horseshoe tunnel.

Problems of Energy Dissipation

The combination of a high inlet head and 294 feet of fall in the bypass conduit results in extremely high velocities in the outlet structure under steady flow conditions. Most of this kinetic energy must be quickly dissipated in the outlet structure before discharge into the outlet channel, in order to avoid damage to the channel and raw-water settling basin.

A design was developed for the outlet structure, as shown on Figure 3. Note that after reduction from 42-inch to 18-inch diameter pipe, water flows through an 18-inch cone valve and passes into an energy dissipating chamber as a submerged jet with a velocity of almost 100 feet per second. Primary energy dissipation is accomplished by the impingement of this jet on a semi-circular baffle, made of steel-armored reinforced concrete, where flow lines are reversed 180 degrees in direction. After leaving the baffle, flow takes a second reversal then passes over a weir to a rip-rapped outlet channel leading to the raw-water settling basin. The main function of the weir is to maintain a pool in the chamber so as to dissipate energy by submergence of the jet. Resultant velocities over the weir are in the order of 4 feet per second.

With Cobble Mountain Reservoir down approximately 25 feet, the calculated energy dissipation under various flow conditions is shown on Figure 2.

Resisting Hydraulic Thrust

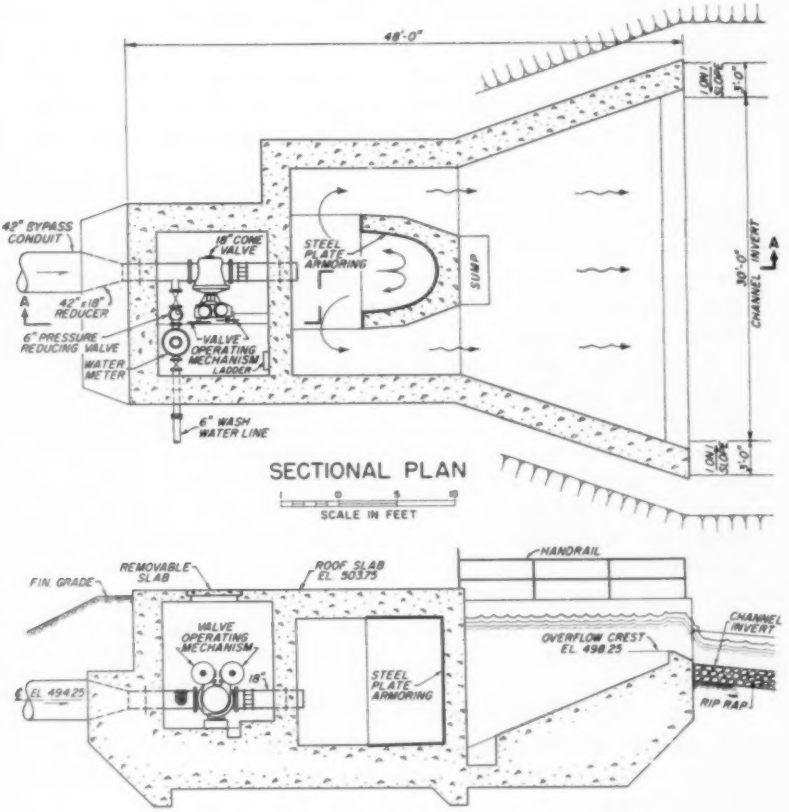
In view of the high velocities and pressures in the bypass conduit, extraordinary measures had to be taken to resist hydraulic thrust.

The greatest thrusts are dealt with in the outlet structure, at the energy dissipating baffle, as follows:

(a) The normal dynamic thrust on the baffle occurs under steady flow conditions when the cone valve is fully opened and

is caused by the momentum of a 100 mgd rate through the 18-inch diameter conduit and the 180-degree reversal at the baffle. The value of this thrust is 53,000 pounds.

(b) The maximum thrust on the outlet structure itself occurs at the instant of shut-off of the cone valve when full static head is exerted. This thrust may be augmented by water hammer



OUTLET WORKS

FIGURE 3

action calculated at approximately 30 pounds per square inch. Its value, including water hammer, is 350,000 pounds. This force is resisted by friction from the dead weight of the outlet structure itself, corrected for buoyancy due to the high ground water conditions since it is located near the raw-water settling basin. The structure required 390 cubic yards of concrete, equivalent to a total dead weight of 1,500,000 pounds.

Because of topography, a total of thirteen anchor blocks were required at elbows on the conduit. These blocks not only resist the high static pressures in the line but also water hammer effects mentioned above. A number of these blocks are located on vertical bends requiring reinforcement and a total weight of concrete, including pipe and water equal to the thrust on the bend.

Appurtenances on the Bypass Conduit

The reinforced-concrete inlet structure houses a 36-inch diameter pivot valve, and a 6-inch air and vacuum relief valve. The structure itself also doubles as an anchor block to resist hydraulic thrust as the pivot valve is opened. This valve is normally opened. It is closed only in the event that the bypass conduit is to be inspected. The pivot valve was manufactured by the Chapman Valve Manufacturing Company.

As shown in Figure 3 the outlet works consist of a reinforced concrete structure containing two chambers, the first of which houses an 18-inch throttling cone valve and a 6-inch diameter branch pipe for wash water to the filters, while the second is the energy dissipating chamber. A 2-inch fill pipe in this chamber permits a pool to be established to submerge the entering jet, and a drain is provided to empty the chamber to prevent freezing problems. (The fill and drain pipes are not shown). An orifice plate may be attached to the end of the 18-inch pipe to further throttle flows should operations so require. A rip-rapped lined channel connects the overflow weir to the raw-water settling basin at the filter plant.

The 18-inch cone valve has dual operating mechanisms; one to rotate the plug valve, the other to lift and seat the plug in any throttled position. Shut-off of the bypass conduit is accomplished by this valve, which was manufactured by the Chapman Valve Manufacturing Company.

The 6-inch reducing valve on the wash water line reduces pressures from a maximum inlet pressure of 235 psi to a steady outlet pressure of 150 psi. This valve was manufactured by the Golden Anderson Valve Specialty Company. Water taken from the bypass conduit for wash water purposes is metered.

There is a reinforced concrete chamber over the 42-inch conduit immediately upstream of the outlet structure housing a 42-inch propeller type meter. This meter and the meter on the 6-inch wash-water line enables the city to credit Western Massachusetts Electric Company for water which bypasses the hydroelectric plant. The 42-inch propeller-type meter was manufactured by the Measure-Rite Meter Company and is calibrated to measure flows from 10 to 100 mgd.

At each of the two low points in the conduit is a 6-inch diameter blowoff terminating in a small reinforced-concrete chamber. Each of these chambers contains a concrete baffle to dissipate the energy of the jet action due to blowoff operations. The water from the upper blowoff spills onto a rubble area and finds its way into the intake reservoir; the water from the lower blowoff spills onto a rubble area and finds its ways into the Little River downstream of the intake reservoir dam.

The Contract and Construction

The contract was awarded to R. Zoppo Company at a bid price of $724,380. This bid was the lowest of four bids received, ranging from $724,380 to $1,401,950. The probable reason for this spread in the bids were due to the difficulty in evaluating:

(1) The risks involved in the removal of material from the intake reservoir, and

(2) The high damage clauses stipulated in the specifications, namely:

(a) Payment by the contractor to the city of $2500.00 per day for each day in excess of the 62 days stipulated for the removal operations in the reservoir, and

(b) Complete liability by the contractor for all claims for damages by the Stevens Paper Company if his operations caused an apparent color in excess of 20 ppm in the water flowing past the intake reservoir dam.

The high damage clause (a) of $2500.00 per day was necessary to compensate the city against further loss of revenue from the leased hydroelectric plant beyond the $42,000 made necessary by the plant's being inoperative for 62 days. The reason for the second damage clause (b) is obvious.

The contractor's bid for the excavation in the intake reservoir was $144,000 amounting to approximately $1.50 per cubic yard. This included removal and transportation of all materials. As may be noted on Figure 2, the contractor was restricted to three areas for disposal of nearly 100,000 cubic yards of material.

For the 42-inch diameter conduit, the contract specified three alternate types of pipe: reinforced concrete cylinder pipe, not prestressed; prestressed reinforced concrete cylinder pipe; and steel pipe, cement mortar coated and lined. Each pipe was to be manufactured to meet AWWA Specifications and alternate bid prices were required. The unit bid for 9,440 feet of 42-inch conduit furnished and installed indicated the prestressed concrete cylinder pipe to be the cheapest of the alternates at a unit price of $29.50 per linear foot. Bids were as high as $79.00 per linear foot for the steel pipe alternate. Accordingly, prestressed concrete cylinder pipe was used. This pipe was manufactured by the Lock Joint Pipe Co. No difficulty was experienced during pipe-laying operations despite the narrow access road in which most of it had to be installed.

To satisfy the terms of the agreement with Western Massachusetts Electric Company, the contract stipulated that only 7 days would be allowed for making the connection to the 10-foot diameter tunnel at the surge tank, and that the bypass conduit had to be completed and turned into service prior to July 1, 1959, before removal operations were started in the intake reservoir. The contractor completed the initial phase within three days and the latter phase shortly before July 1, 1959.

The contractor desired to commence preparation for the handling of materials removed from the intake reservoir concurrently with the completion of the work of the bypass conduit. To permit this, on July 1, 1959, water was discharged from the intake dam by Water Department personnel using the outlet conduit and blowoff pipe at the base of the dam. A two-stage

conveyor belt system, each approximately 1100 feet long, of 300 tons per hour capacity was then built on a temporary trestle. The conveyor belt entered the intake reservoir through the diversion gate some 8 feet below the crest of the dam and terminated at disposal area No. 1. The total rise in elevation to this disposal area was about 300 feet.

As soon as the reservoir was dewatered, the contractor by means of three front end loaders, three bulldozers, a ¾-yard clam-shell crane, a 1½ cubic yard dragline crane and necessary personnel commenced moving material in the reservoir bed toward a Barber-Greene movable conveyor, located near the dam, which lifted the materials to the main belt conveyor. At the discharge end of the two-stage conveyor, a bulldozer spread the material at disposal area No. 1. Using a 26-inch wide belt, the contractor transported all of the smaller material by conveyor, but the larger boulders and trees were transported by truck up the narrow, steep roads. The 100,000 cubic yards of material was moved at an average rate of 3,000 cubic yards per day.

On July 20, 1959, a storm deposited approximately 3 inches of rainfall. Although Cobble Mountain Reservoir was purposely drawn down approximately 25 feet to provide a reserve capacity, the 2.5 square miles of catchment area downstream of Cobble Mountain caused the intake reservoir level to rise approximately 3 feet when the blowoff pipe plugged with silt. Fortunately, the contractor's equipment was on higher ground in the bed of the reservoir so that no equipment losses occurred.

Two sampling points were selected for analysis of turbidity while removal operations in the reservoir were in progress. One was located approximately two miles below the intake reservoir, the other approximately four miles below the reservoir, at the dam of the Stevens Paper Company. The contract stipulated that the turbidity at no time should exceed 20 ppm. The average turbidity was maintained at 3.0 ppm by means of temporary stilling basins immediately downstream of the intake reservoir dam. Although the July 20, 1959 storm caused an increase in turbidity of a maximum of 800 ppm, this abated within 5 days to 8 ppm and immediately thereafter to the normal of 3.0 ppm. Fortunately, the paper mill was on a vacation schedule.

Starting Operations

Immediately upon completion of the bypass conduit with the cone valve at the outlet structure and the two blowoffs closed, the inlet pivot valve was cracked, permitting water to enter the bypass conduit. Air at the two high points was released by means of manually-operated air valves, installed for that purpose. The cone valve at the outlet was then opened gradually and observed in various throttled positions. It was found that when the valve was in the ½ to ¾ open position, vibrations within the chamber were highest. In all other positions, vibration was at a tolerable level. Unfortunately, since the 42-inch propeller meter was not received in time, it could not be installed either during this trial run or during actual operation this past summer. A check was made of the flow by measurement of the levels in the raw-water basin and by use of the venturi meters at the filter plant. The flow, when the 18-inch cone valve was fully opened, was found to be approximately 120 mgd. The valve under service did not prove entirely satisfactory. For this reason, the operating mechanism is presently being rebuilt, to strengthen it and improve operating control.

Conclusions and Credits

Good contracting operations by the R. Zoppo Construction Co. permitted rapid and efficient removal of flood debris from an important water-supply reservoir.

More important, the Board of Water Commissioners by this project has benefited the city of Springfield by providing (1) a high-capacity bypass conduit for a vulnerable portion of the main supply system and (2) a permanent facility to make any subsequent excavation in the intake reservoir more economical.

The Massachusetts Flood Relief Board, set up to assist municipalities to repair flood damages caused by these major storms, provided financial assistance. This amounted to half the contract cost, or approximately $362,000. The remainder was financed by the city through the sale of a $500,000 bond issue.

The design of the bypass conduit and supervision of construction of the work was done by Clinton Bogert Engineers (formerly Bogert and Childs).

OPERATION OF THE LAKE WHITNEY FILTERS AND USE OF THE DORRCLONE SAND WASHER

BY SAMUEL JACOBSON*

[*Read Apr. 21, 1960.*]

One hundred years ago, the New Haven Water Company started the construction of its first dam at the foot of East Rock, known since colonial times as "Point of Rocks." Here, early settlers of New Haven had operated grist mills. The national defense of 1798 led to the development of the stream as a major source of power when Eli Whitney, the inventor, bought the mill site and erected the Whitneyville Armory, at that time the largest armory in the United States. The principle of mass production, which has been developed to such a degree in our country, originated in this armory, when Whitney began to produce firearms with standardized, interchangeable parts for the first time in history.

On January 1, 1862, the New Haven Water Company began distributing water from Lake Whitney, which had an available storage of 170 mil gal. In 1904, when the watershed had become thickly populated, the company started construction of the filtration plant as an added precaution. The covered slow sand filter was completed in 1906. As early as 1909, it was found that during dry weather there was difficulty in getting enough water into the filters on the west end of the plant to operate them, and the float-operated gauges could not work. In 1916, the old spillway was raised 19 inches to an elevation of 33.0 feet and its length was increased to 250 feet to maintain the original flood level. To obtain the extra length, a trough or side channel, measuring 61 feet in length, was built along the east side. The available storage was increased to 258 mil gal, and no further trouble has been experienced in keeping the filters at their required level.

Sixteen other reservoirs have been added to the system, but the Lake Whitney supply is still one of the more important,

*Director of Laboratory, New Haven Water Co., New Haven 6, Conn.

due to its watershed of 37.7 square miles and good dry-weather yield. It has been estimated that its safe yield for a 95 per cent dry year is approximately 7 mgd. During the 40-year period from 1918 to 1957 the average flow at the Whitney Dam was 42 mgd. The minimum annual average flow for the period was 26 mgd. in 1930, and the maximum annual average of 77.2 mgd. occurred in 1953. During 1959, the color of the untreated water varied from 15 to 125, averaging 33. The turbidity varied from 3 to 68, averaging 11. Although this water must be filtered (1), its potential for future use is considerable (2).

The Lake Whitney Filter Plant has twelve slow sand filters, each one-third of an acre in area. Normally eleven filters are operating. The water enters each bed from a five-foot-square concrete well, the top of which is a few inches above the level of the sand. The depth of water in the filter is maintained by a float in this well. The water seeps through an average of 36 inches of sand and flows through a pipe equipped with a Venturi tube-meter. There are connections to a cross-over pipe, by which any bed can be backfilled with filtered water, and also connections to waste from either the top of the filter or from the underdrain system. The water is chlorinated and flows into a 750,000-gallon clear well on its way to the pump house and the distribution system.

The sand-washing methods employed are, we believe, the most practical for the conditions encountered here. When clogged a filter must be taken out of service, drained to waste, and the upper ½-inch of sand scraped off and washed in an Allen Hazen sand washer. The washed sand is transferred hydraulically to a filter, whose sand level is being raised from a minimum of 30 inches to a maximum of 44 inches. To avoid stratification, much of the movement of the sand is by wheelbarrow rather than by hydraulic placement. Each filter goes through its cycle of being a "sand bed."

The plant went into service with an average of 33 inches of sand. In 1927 and again in 1939, new sand was added, increasing the average depth 8 inches. At present we have an average of 36 inches of sand, so that 5 inches of sand have been lost in 54 years of operation, or about 0.1 of an inch of sand per year, which includes losses due to compaction.

Until 1957 none of the filters had been cleaned to the gravel, so that at least 18 inches of bottom sand had not been cleaned in over 50 years. The long use of the filters under such conditions can be credited to the careful operation of the plant and the avoidance of raking for as long as possible. In 1930, memorable because of a drought, very heavy growths of algae were reported—probably an effect of the building boom of the 20's. In December, 1930, for the first time in the history of the plant, the beds were raked and washed by lateral flow, but the procedure was always considered an emergency operation. The highest average daily rate of filtration during any year was 12.83 mgd. in 1918, when the largest total annual volume filtered was 4,682 mil gal. From the earliest days of the plant, high color and turbidity in the applied water were experienced during the spring and fall after heavy run-off, but satisfactory water was almost always obtained in the effluent. An exceptional condition occurred during the severe winter of 1917-1918, when the filters froze over in part, making cleaning operations very difficult. A piece of ice as large as a soda cracker would stop the ejectors. On February 20, 1918, unusual weather caused the raw water turbidity to reach 180 and the effluent turbidity was 30. Postchlorination was installed at that time and has been used continuously.

Because of the practice of keeping one filter out of service as a sand bed, about 8 per cent of the plant's capacity was not being realized. As an experiment in 1917, washed sand was spread out over cleaned beds and raked in with a cultivator. When these re-sanded beds were examined, it was found that the water went through the washed sand and filtered on the original surface; even where the cultivator teeth went through the old surface, the water followed this disturbed deck and filtered below it. In every case this was true, and it was predicted that the filter would be ruined if this practice was continued. One bed has been kept out of service as a sand bed ever since. Our more recent observations have shown that stratification also takes place at the lower levels, even though at a much slower rate.

The duration of filter runs at our plant has been mainly dependent on (a.) the concentration of filter-clogging materials—chiefly algae, amorphous matter, inorganic sediments, and dis-

solved substances such as iron and manganese—(b.) filter rates, and (c.) the penetration of sediments and fine sand into the lower levels to produce stratification. The effects of most conditions can be more quickly observed than the effect of changes in the sand. To improve the filtrability of the water, we have been treating the reservoir with copper sulfate and continuing our efforts to prevent unsanitary conditions. Soil washings during construction activities have been almost impossible to control. A continuing building boom and street extensions have not alleviated the situation.

The New Haven Water Company was among the first to use free residual chlorination for disinfection of unfiltered supplies, starting in 1944 (3). Prechlorination was being used successfully at rapid sand filter plants, but was rarely used on slow sand filters because of the possibility of high bacterial counts and poor quality water. With the better control offered by free residual chlorination, experimentation with individual filters indicated that satisfactory results, including improved bacteriological quality, longer filter runs and satisfactory water quality, could be obtained (4). Further observations have shown that free residual chlorination of the filter effluent was necessary to provide satisfactory water at all times.

Our records show that from 1907 to 1926, the annual average volume of water filtered per cleaning varied from a minimum of 150 mga. to a maximum of 264 mga. This was followed by a progressive decrease in filter output, due for the most part to changes in filtrability of the water. From 1941 to 1949 the volume of water filtered per cleaning varied from an average of 78 mga. to 165 mga.

When prechlorination was applied to the entire plant on April 12, 1949, greatly increased filter runs were obtained for a time. In 1950 the average was 282 mga., or 119 per cent more than the average for the preceding nine years. The next year the average filtered per cleaning decreased to 216 mga. and then continued to decline. We found that prechlorination disturbed the normal filtering mechanism, so that there was a gradual penetration of the sand which our sand-washing practice could not correct. Certain difficulties characteristic of prechlorination, such as sloughing off of bacteria and the development of taste

and odor, resulting from the gradual cleaning of the sand by chlorine, had been observed during trial runs, but effects were later revealed that had not been anticipated—that is, a gradual darkening of the sand, accompanied by increasing initial loss of head, inability to achieve a continuous chlorine residual in the effluent, and complaints from plant operators of eye irritation when doses as high as 6 ppm. were used. On December 31, 1955, after almost 7 years of prechlorination the practice was abandoned, mainly because of the continuing increase of initial loss of head, which in certain instances exceeded 3 feet.

Weekly examinations of the Lake Whitney untreated water from 1952 to 1955, inclusive, showed that high manganese and iron occurred usually in the fall. Normally the iron, and particularly the manganese, concentrations were small. During that period, the highest concentration observed was 0.40 ppm. of manganese on September 1, 1954, following heavy rain. The highest concentration of iron observed was 1.24 ppm. on October 9, 1953.

Although manganese and iron are factors in filter clogging, our data do not explain the mechanism of this clogging. It appears that, together with algae and sediments, iron and manganese can produce surface clogging, and within the filter sand they can build up sediments clogging the voids. Even without prechlorination, these effects can take place. As early as October, 1916, Walter J. Connor, at that time Superintendent of Filtration, reported, "The water in the lake was low and for some reason the beds closed quicker than ever before, as it was but two weeks since the filter was cleaned. Judging from past performance, it was thought the beds were good for another week and there was ample time to do the cleaning, but we were in error." Similar instances have occurred since that time.

We have made analyses of the sand from different levels. The samples were extracted with 5-Normal hydrochloric acid for 24 hours at room temperature, and the filtered washings were analyzed for iron and manganese. We found manganese present in all samples, decreasing in amount from an average of 3.19 mg. at the top of the filter bed to 2.54 mg. per 100 gm. of sand at the bottom. The iron content, on the other hand, increased from an average of 394 mg. at the top to 701 mg. per 100 gm.

of sand at the bottom. We know that this filter has sand of local origin in its lower levels, which would be probably higher in iron than the Long Island sand in the top layer. Further work along this line would be of interest.

The sizes of sand grains are an important factor in the operation of the filter, since they materially influence the rate of filtration. As far as the transmission of the water is concerned, the influence of the finest sand grains is far greater in proportion to their number than that of the coarser particles.

Sand-size analyses (Taylor sieve tests) were made of top, middle and bottom sand samples, as shown in Table 1. The

TABLE 1—SAND ANALYSES AT LAKE WHITNEY FILTRATION PLANT

Depth	0"	15"	30"	30" DorrClone
	Bed No. 1			
Effective Size (mm.)	0.305	0.268	0.245	0.263
Uniformity Coefficient	2.19	2.43	2.73	2.89
Turbidity (10 gms./100 ml H_2O)	245.0	1110.0	773.0	182.0
	Bed No. 2			
Effective Size (mm.)	0.306	0.257	0.249	
Uniformity Coefficient	2.13	2.56	2.85	

average effective sizes decreased from 0.305 to 0.245 mm., indicating the movement of the fines to the bottom of the filter. The average uniformity coefficients, on the other hand, increased from 2.19 to 2.73, indicating less uniformity of grain size at the lower depths. Similar results were obtained with samples from another bed. The results indicate that there has been a gradual downward movement of fines and less uniform grain sizes with increasing depth.

Turbidity determinations were made on 100-ml. washings from 10-gm. samples of sand. The average values increased from 245 at the top to 1110 at the 15" depth and then decreased to 773 at the 30" depth, indicating stratification at the 15" level, where a dark layer began.

An attempt was made to recondition all the sand in a filter, using the Allen Hazen sand washer. This procedure was not

practical in reconditioning of sand because of the labor involved in moving over 1300 cu. yards. We needed a machine that could satisfy the following requirements: That it be able to pass through an opening 6½ ft. in width and 5 ft. in height; that it be able to pass under the beams and pipes in the filter; that it be maneuverable enough to be handled by four men; that it use no more than 10,000 gallons of water per hour; that it be able to wash adequately 10 cu. yards of sand per hour without significant losses, and that it deliver the sand near where it was to remain. The resulting DorrClone sand washer (Fig. 1) was designed by us and the W. H. Milroy and Company. It consists essentially of an Allen-Sherman-Hoff Co. "Hydroseal" split-shell slurry pump, Frame A-6-5, with 10-hp motor and variable-speed drive and a DorrClone 12″-diameter × 20° cone, Type FR, manufactured by Dorr-Oliver Incorporated. We are using a completely rubber-lined DorrClone with 5″ vortex finder and a 2″ adjustable apex opening.

The DorrClone is a classification and desliming device of cylindro-conical shape, utilizing centrifugal force in place of gravity to effect the separation of different sizes of solids suspended in water. The sand suspension is pumped to tangential inlets at sufficient pressure to induce a rapid swirling of the slurry. This centrifugal force throws the sand to the walls of the conical section and down an orifice at the apex. The cyclonic action sets up a vortex in the main body of liquid containing the fines, which escape, in large part, through the vortex finder and to waste via the overflow pipe. Depending on the critical dimensions of the machine, size analysis of the sand, viscosity of the feed and feed inlet pressure, it is possible to make separations in the range of 20 to 150 microns. The DorrClone is claimed to be able to operate equally well in any position but preferably with the apex discharge as the lowest part of the DorrClone. Special care must be taken in the assembly of the unit to position properly the rubber lining, secured with rubber cement where recommended. If a constant mesh of separation is to be maintained, the feed pressure and flow rate must be constant. Feed pressure is set by adjusting the pump speed so that the DorrClone receives a constant feed volume. If this volume is not fed to the pump, surging and erratic separation will result. The apex valve is adjusted so that a spray discharge just beyond a "rope" dis-

FIG. 1—DORRCLONE SAND WASHER

charge is obtained. For constant machine dimensions the diameter of separation will increase as the pressure is diminished. The sand pump requires a uniform flow of sand and water, having no more than 25 per cent sand by weight. Compacted or frozen masses of sand must be completely broken up, or the machine will not

operate properly. Stones up to one inch in diameter can easily pass through, but large ones will block the rubber-lined impeller of the sand pump, causing loss of pressure and flooding. The movement of the sand washer had to be planned so that it would pass between all the columns and finish the reconditioning at the door, where it could be disassembled and removed.

Various modifications on the original design have been made. The trough was raised about 6″, to help smooth out the operation and prevent air-binding of the pump. The splash plate was raised, to give the men a larger target for shoveling. A perforated pipe was installed along this plate, to spray the sand and help break it up. The water jets were removed and replaced by two ½-inch pipes, located 18″ and 36″ along the trough, to keep the sand moving toward the suction. Crossed wires were installed in the suction of the pump, to prevent large objects from entering. A syphon breaker was inserted into the overflow pipe, to prevent the pulling of sand into the overflow. An arrangement for the recirculation of wash water was installed, to maintain the water level in the trough, but it was later removed, because it prevented the rotation of the overflow pipe and was actually unnecessary.

The sand from the 30″ depth after passing through the DorrClone showed a small increase in effective size and in uniformity coefficient. The turbidity value showed that about 77 per cent of the suspendable matter had been removed. Three reconditioned filter beds have been returned to service with low initial head loss, such as 0.2 feet at a 3-mga. rate.

Our filter-reconditioning program, based on a DorrClone sand washer of original design, has resulted in (a) the break-up of the stratified and compacted sand, (b) the removal of accumulated fine sediments, and (c) recovery of low initial head loss.

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MEMOIR OF CALEB MILLS SAVILLE

Caleb Mills Saville, nationally recognized authority in the field of hydraulic and water-supply engineering, was born in Melrose, Mass., on May 27, 1865, and died in Hartford, Conn., February 14, 1960.

Mr. Saville grew up in Medford, prepared for college at Stone's School in Boston, and was graduated in 1889 from Harvard University *cum laude* in civil engineering. The years immediately following his graduation were spent on various engineering projects in the Boston area.

From 1895 to 1905 he was Division Engineer for the Metropolitan Water Board of Boston and in charge of design and construction of the Wachusett Dam.

As a result of this work, he was called in 1907 to accept appointment as Assistant Engineer under General Goethals in charge of investigations for the design of the Gatun Dam at the Panama Canal. The hydraulic model studies which he carried out there were pioneering in character, and his report on these in the Annual Report of the Panama Canal Commission in 1908 was cited as "a masterpiece of engineering investigation". Subsequently he was appointed by General Goethals as Division Engineer in charge of all hydrographic, hydrological and water resources. His paper on the "Hydrology of the Panama Canal" received the Norman Medal, the highest award of the American Society of Civil Engineers.

In 1912 Mr. Saville began his long association with the water-supply system of Hartford, Conn., serving as its Manager and Chief Engineer until 1948, when he was appointed Consultant, in which capacity he continued until his death. He conceived a long-range program for development of major sources of water supply in the Farmington River Valley, which insures an adequate supply of water to the Hartford metropolitan area until the end of the century.

Two of the three water-supply projects envisioned in this program were completed during his tenure as Manager and Chief

Engineer, and the dam which impounds the larger of the two reservoirs was named the Saville Dam in his honor.

Mr. Saville was the author of numerous technical papers, and he was active in many technical societies and associations. He had been a member of the New England Water Works Association since 1893, was its President in 1917 and became an honorary member in 1929. He was a member of the American Water Works Associaton, American Society of Civil Engineers, Boston Society of Civil Engineers, American Meteorological Society, Royal Meteorological Society of England, and American Geographic Union, an honorary member of the Connecticut Society of Civil Engineers and a life member of the Institution of Water Engineers of England.

Among the many honors accorded to him during his life, in addition to the Norman Medal of the American Society of Civil Engineers in 1914, were the Dexter Brackett Memorial Medal of the New England Water Works Association in 1917, 1927 and 1934, and the President's Premium of the Institution of Water Engineers of England in 1932 and 1939.

He also belonged to the Society of Colonial Wars, Society of Mayflower Descendants, Harvard Club and the University Club.

Mr. Saville is survived by a son, Dr. Thorndike Saville, retired Dean of the School of Engineering of New York University, a grandson and three great-grandchildren.

Caleb Mills Saville contributed much to the water-supply industry in general and to the Hartford water-supply system in particular.

The Hartford Times, in its editorial comment on Mr. Saville's death, reads in part as follows: "He was an apostle of thoroughness, of integrity, of diligence and of practical accomplishments for the welfare of future generations. We are fortunate to have had him with us for so many years and to inherit the great water supply that he helped to create".

WARREN A. GENTNER

PROCEEDINGS

April 1960 Meeting

New Haven Lawn Club, New Haven, Conn.

Thursday, April 21, 1960

The Southern New England meeting of the New England Water Works Association was held in New Haven, Conn., on Thursday, April 21, 1960.

Over 180 members and their guests assembled at the Operations Building of the New Haven Water Co. and inspected the new facilities. Coffee and doughnuts were served. The group boarded busses to Lake Chamberlain for inspection of the dam which had recently been raised 37 feet.

Luncheon was served at the New Haven Lawn Club with President Warren A. Gentner presiding. After the introduction of those at the head table, greetings were given by Arthur L. Corbin, Jr., President of the New Haven Water Co.

A paper on "New Haven Redevelopment Program" was read by Frank O'Brion, Chairman of the New Haven Redevelopment Agency and President of Tradesmens National Bank, New Haven, Conn.

A paper on "Operation of Lake Whitney Filters and Use of DorrClone Sand Washer" was read by Dr. Samuel Jacobson, Director of Laboratory, New Haven Water Co., New Haven, Conn.

May 1960 Meeting

Hotel Northampton, Northampton, Mass.

Thursday, May 19, 1960

Approximately 150 members and guests attended the Northern New England meeting of the New England Water Works Association at Northampton, Mass., on Thursday, May 19, 1960. Upon arrival at the Western Massachusetts Public Health Center in Amherst, where coffee and doughnuts were served, they proceeded on guided tours through the new Health Center.

Luncheon was served at the Hotel Northampton, after which the greetings of the city of Northampton were given by the Mayor, Hon. Durbin H. Wells. President Warren A. Gentner then introduced the Water Commissioners of the city of Northampton.

A paper, entitled "Operation of a Combined Surface-Ground Water Supply—City of Northampton," was read by Francis M. Hennessey, Superintendent, Water Department, Northampton, Mass.

A paper on "Water Resources of the Connecticut Valley" was read by Angelo Iantosca, Associate Sanitary Engineer, Massachusetts Department of Public Health, Amherst, Mass.

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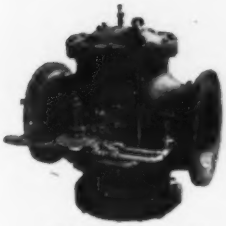

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Maintains desired discharge regardless of change in rate of flow pressure

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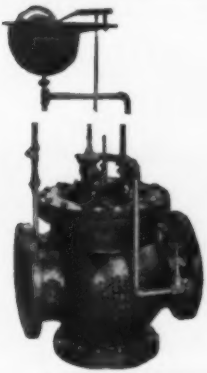

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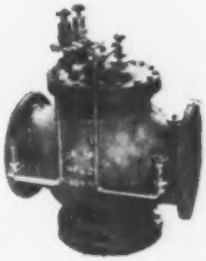

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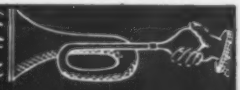

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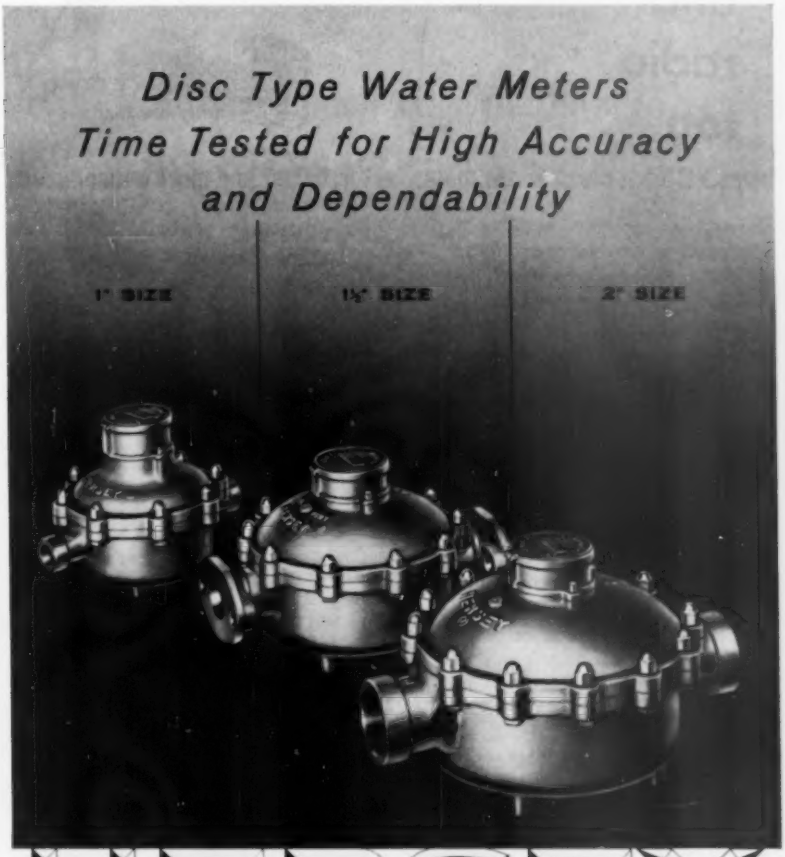

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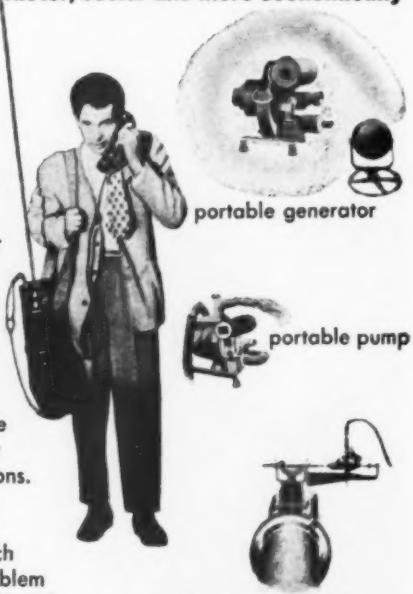

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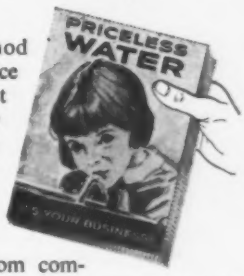

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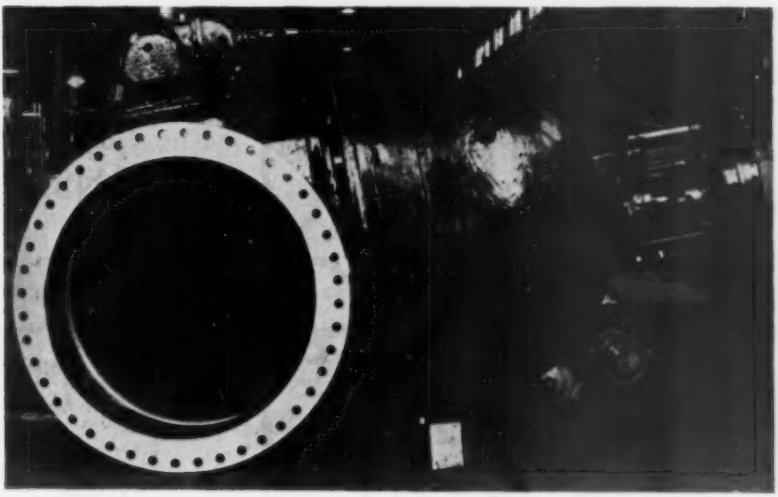

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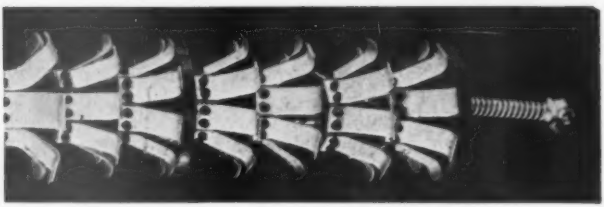

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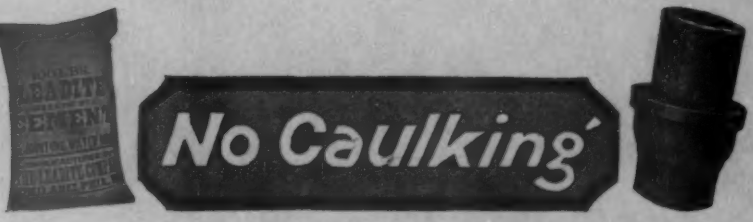
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